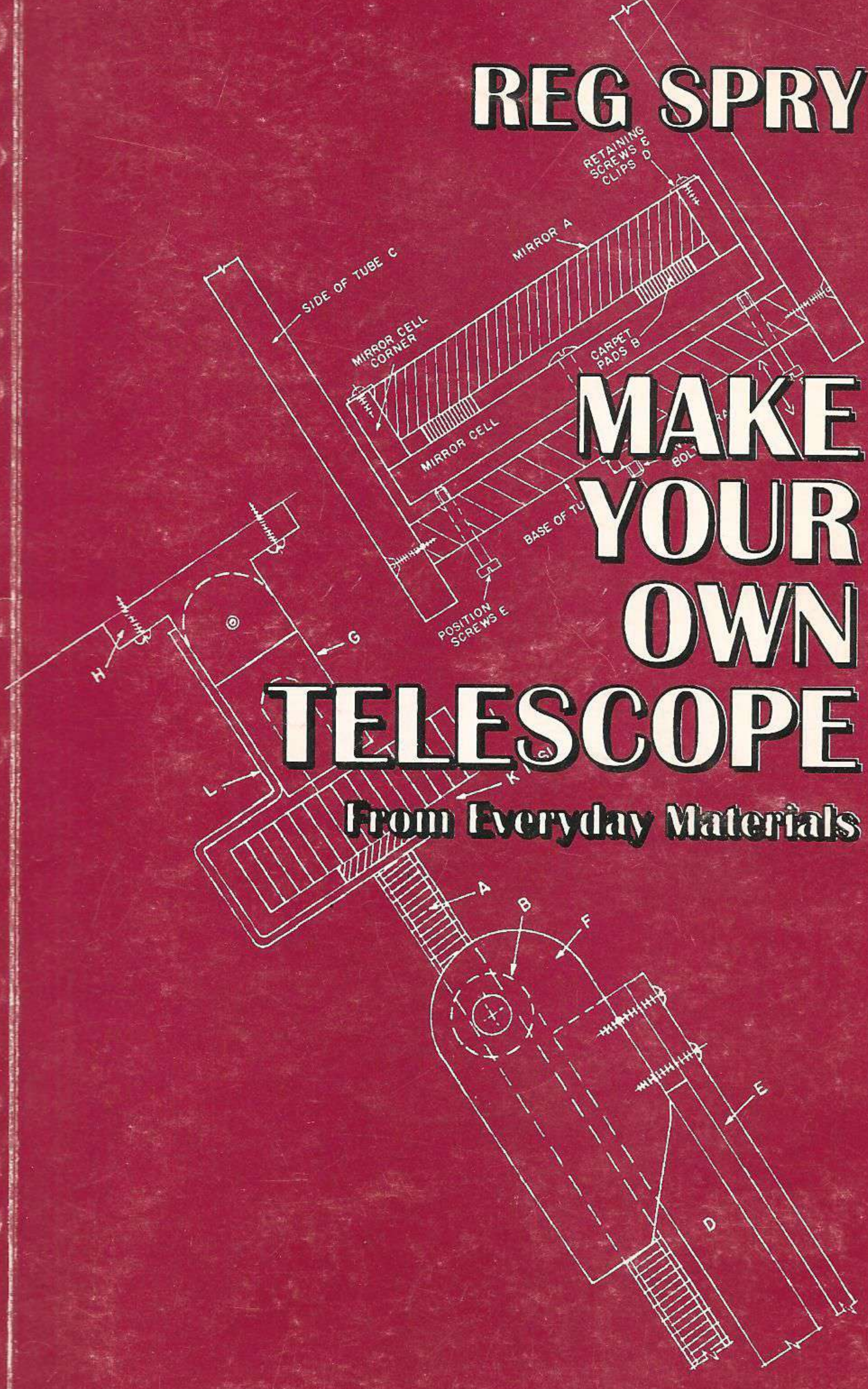
REG SPRY

MAKE YOUR OWN TELESCOPE

From Everyday Materials



Make Your Own Telescope

From Everyday Materials

Reg Spry

Former Council Member of the
British Astronomical Association

SOUTH DOWNS
PLANETARIUM

South Downs Planetarium Heritage Series
Reprints of key publications in astronomy

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PATRICK MOORE
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PATRICK MOORE

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Foreword

Many books have been written on the subject of telescope-making, and many others dealing with astronomical observing. The literature is, in fact, vast; but all the telescope-making books known to me concentrate largely upon optics rather than upon the 'hardware'. This new book is different, because it assumes that the optics have already been obtained, and goes on to deal fully with the problems of making the mounting and the observatory.

Reg Spry is the classic example of a man who started making a really serious hobby of astronomy when he was nearing what is normally known as retirement age. He has a genius for making things and adapting things, and the results which he produces are truly remarkable, particularly in view of his fondness for pressing into service articles which are normally regarded as strictly non-astronomical. In this book he describes his 6-inch reflector, made at a total cost of approximately £5 if we neglect the optics. The telescope incorporates such items as coffee-jar tops, *Meccano,* and a car half-shaft. I have used the telescope many times, and it is probably the most convenient 6-inch reflector that I have ever handled.

He says that he hopes 'at least one beginner' will be inspired to follow his example. I suspect that there will be not one, but many beginners who will do so, and will be profoundly grateful to him for guiding them. I certainly hope so.

Patrick Moore

Selsey, 1978

Foreword to this edition

Reg Spry was an unusual astronomer. He did not pretend to be either a theorist or a practical observer; neither was he a skilled optical worker, and he came to astronomy late in life - in fact, at the age of sixty five. But when it came to constructing 'hardware' for telescopes and observatories, he showed that he had remarkable ability. Moreover, he was able to make excellent equipment out of what might be called 'bits and pieces'. The tube for his first telescope was made from a pair of dismantled larder shelves.

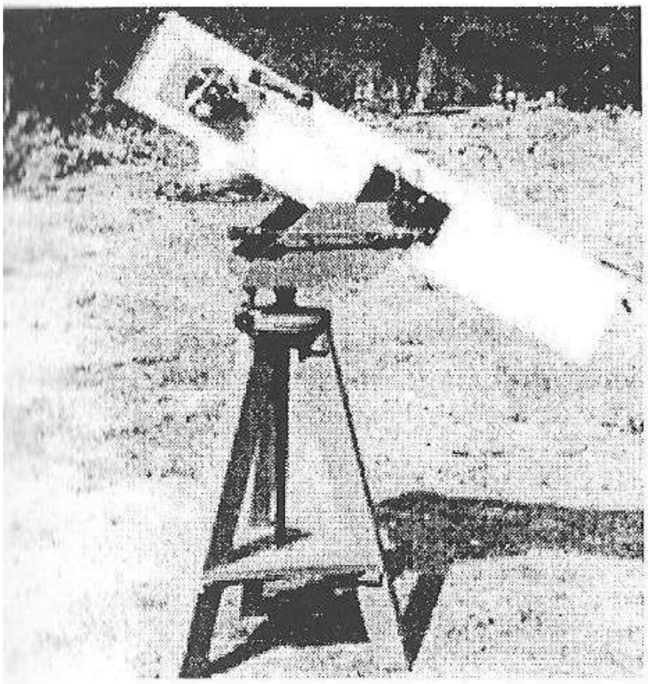
He became a leading member of the South Downs Astronomical Society; he gave numerous talks all over the country, and he also broadcast - always on his own particular subject. He then wrote this book, and it was well received.

Unfortunately it has been out of print for some years, and Reg Spry died in 1989; he is greatly missed. But it is right that the Planetarium should republish his book, which has been of immense value to those who are anxious to build telescopes and observatories of their own. Moreover, there is no other book quite like it, and its reissue now is a tribute to the memory of Reg himself - skilled amateur telescope-maker and a very dear friend.

Patrick Moore

Selsey, 1997

Readers should be aware that prices quoted for materials are those of 1977. Adjustment for inflation should be made accordingly!
Original photographs were not available, and there has been a slight loss of quality in the scanning process.



Introduction

Astronomy is a growing science. During the past few decades it has blossomed from a study for the relative few into an interest which is shared by almost everyone - though, admittedly, in various degrees. We have seen men on the Moon, probes to the planets, and discussions about things as exotic as pulsars, quasars, and black holes.

And yet astronomy is still one of the best of all hobbies, if only because the amateur can continue to play a role which is really useful. There are some amateurs who have no optical aids at all, and concentrate upon naked-eye work: observations of meteors, for instance, or auroræ. However, most amateurs will need something in the way of telescopic equipment, and this is often where the trouble begins, because in the present age of inflation telescopes which are of any real help in astronomy are far from cheap.

It is ironical to look back over old catalogues, to see pre-war prices. In the 1930s, a 3-inch refractor could be obtained very cheaply, and a 6-inch reflector about the same. Today one must give serious consideration to cost. True, the expense is non-recurring; once a telescope has been bought and erected it will last for a lifetime. The maintenance is slight for a reflector, and virtually nil for a refractor. But there is always the problem of the initial outlay; many beginners are of school age, and spending a lot of money is out of the question.

The obvious solution is to make a telescope for oneself, and this is quite practicable. Fitting up a small refractor, made out of spectacle-type lenses, is easy enough once the lenses have been obtained. They do not cost much; the difficulty nowadays is in locating them. On the other hand, a refractor of this type is bound to be low-powered and of poor quality. If a bigger refractor is wanted, the object-glass is the first priority. Few amateurs can tackle lens-making, and since most of the cost of a refractor lies in the optics there is not really much point in buying a large object-glass and then making a mount for it. It is much better to buy the refractor complete - but be prepared for a great deal of expense.

Though lens-making is a real problem, to be reserved for the gifted and persevering few, mirror-making is a different proposition altogether, and is within the scope of anyone who is reasonably good with his (or her) hands. The favourite aperture for one's first telescope is 6 inches for the main mirror. (The secondary, or flat, is smaller, and generally purchased from a professional maker.) The aspiring mirror-grinder must be ready for many disappointments, and is bound to feel frustrated when things go wrong, but eventually he will succeed, and if he wishes he can then go on to make a mirror of larger size. When difficulties arise, the essential is to keep one's sense of proportion, and refrain from hurling the mirror to the ground and stamping on it. After all, Sir William Herschel, who became the best mirror-maker of his time (late eighteenth and early nineteenth centuries) had over two hundred failures before he produced a mirror which was even reasonable. Later in his career he made, and used, a mirror with an aperture of 49 inches!

Mirror-making has become popular in many astronomical societies, and there are many books about it. There are also many books about how to use the telescope when it has been completed, and there are some comprehensive volumes which cover practically everything. This being so, the reader may ask why yet another book is being added to the catalogue. The answer is that this present book is limited in scope to special kinds of telescopes - one telescope in particular - and says virtually nothing about mirror-making, or optics as a whole.

I am not a mirror-maker. I would not claim to be one. Neither, for that matter, do I regard myself as a serious observer, though I take part in certain observational programmes when required (for instance, in studying the interesting phenomena known as occultations). So I would not set out to write about these topics. My own speciality is in what may be termed 'hardware' - the actual construction of the telescope, once the optics have been obtained.

I may add that I do not believe in buying more than is absolutely necessary, and I have a large box which is full of bits and pieces; it is generally known as the 'It-may-come-in-useful-one-day' box - and it does! When the idea of making a really workmanlike 6-inch reflector was put into my head, I set out to construct it with as little expense as possible. I also determined to work with very simple tools. I admit that I do have a workshop which is, by ordinary standards, well-equipped, and includes an excellent lathe; but for the telescope to be described in this book I deliberately avoided using the lathe, or anything else apart from a few saws, screwdrivers and the like. This proved to be quite sufficient for the completion of a basic telescope which worked well. Adding a few refinements meant making use of the workshop, but I do not think that this can be classed as cheating, because all the basic requirements for a telescope were included in the original model.

Now let us calculate the cost - bearing in mind that I am writing these words in August 1977, and things may have worsened by the time that the book appears in print.

Catalogue price for a basic 6-inch reflector: let us say£100 or $200. To add a rack and pinion eyepiece mount, slow motions, etc., another £20 or $40 at least. For a clock-driven equatorial mount - well, £180 ($360) is a conservative estimate nowadays.

Now let us consider the Spry model; it was made in 1975 and these are 1975 prices, so that they do have to be increased now. Cost of the optics (mirror and flat): £20 ($40). A first eyepiece: £3 ($6). All the materials for the mounting, including slow motions, about £1.50 ($3). This meant a total outlay of £25 ($50), bearing in mind that one was prepared to do all the work oneself, and was ready to look around for suitable materials which could be pressed into service.

Now, £25 ($50) is not an impossible figure for most people at the present time, and putting by a small amount each week for a few months will deal with it. (I used to spend this sort of money on cigarettes, until I had the wisdom to give up smoking altogether.) By now I admit that the sum has to be increased, but certainly by not more than fifty per cent. And if you follow the leads given in this book, I assure you that for about £35 ($70) you will end up with a telescope which is not only good enough to give you pleasure, but is also good enough to allow you to carry out valuable observational work in collaboration with others if you so wish.

Sometime ago I was talking to a friend of mine who is a really enthusiastic observer, but admits to being hopelessly clumsy when it comes to making things. Initially he was dubious as to whether a telescope costing £35 ($70) would be worth while. But as I stressed, if one has good optics one is bound to finish up with a good telescope - if enough care is taken with the mounting. The main essentials are stability and ease of use and, of course, there is no need to be too ambitious. I quite agree that to make a driven equatorial mount would cost a good deal more than I spent on my 6-inch, but an altazimuth mounting is good enough for many purposes, and in some ways it is an actual advantage; the eyepiece always stays in a convenient position, and the telescope can be swung from one part of the sky to another in a few seconds.

Subsequently, when the telescope was ready, we were together at a week-end astronomy course. Nova Cygni, the new star in the Swan, had blazed up some weeks previously, and had already faded well below naked-eye visibility. My critic took the telescope out on to the lawn (bear in mind that the whole instrument is easily portable), and I timed how long it took him to clamp the telescopic nova firmly in the middle of the field. I think that the time taken was fifty seconds - it may have been rather less.

Next, there is the matter of appearance. Telescopes are generally pictured as sleek, elegant instruments with symmetrical tubes; but, after all, a telescope is meant to be used rather than put aside to be admired, and there is no need to have a cylindrical tube. A square tube will do just as well, and if it is wooden one can at least screw attachments such as finder mounts into it without any difficulty at all. It is often forgotten that the sole function of a telescope is to hold the optical components firmly in the right positions. If it does so, then it is a good tube - whether it is actually tubular or not. Many reflectors have skeleton tubes, which may also be of square construction, and I would not for a moment decry them. For large instruments they are advantageous in view of their lesser weight, but large telescopes are always housed in permanent observatories, and there are no problems with scattered light. On the whole, I prefer a solid tube for a portable amateur instrument of the 6-inch variety, because it is more stable and it cuts out any incipient light trouble; but everyone will have his own ideas. I made my telescope 'solid' because it was definitely easier.

I do not want to underestimate the task of the telescope maker, and it is quite true that an instrument with a wobbly mount will be more or less useless. It may be reasonable when only low-power eyepieces are put in, but a higher magnification inevitably means a smaller field, and stability becomes all-important. I would also say that there are grave difficulties in using even a 6-inch reflector, on an altazimuth mount, without slow motions but all these are included in the pattern which I propose to set before you.

When I set out to compile this book, I meant originally to start by describing small refractors of the spectacle-lens variety; but this has been done before, and there is really no point in going over the old ground again, because it is 99 per cent common sense (moreover, the lenses themselves are rare nowadays). As I have said, if a larger refractor is wanted it is best bought complete. So let us turn to the one kind of telescope only: the basic 6-inch reflector, made with purchased optics and 'scrap' materials which can be collected at almost nil cost.

There is, too, the question of the time needed: this is relevant for teenage enthusiasts who are faced with the pressing problems of examinations. Friends often say to me: 'How long does it take to make this or that?' I am never quite sure what to say. If I am making an article of some kind, and it fails to satisfy me, I simply re-make it, which naturally adds to the time. And if I were to put in two hours every Saturday afternoon from one Christmas to the next, would the whole operation take me 100 hours, 50 days, 50 weeks, 12 months or a year? It all depends on one's method of reckoning.

Once, in my workshop, a friend asked me how long it would take to make a telescope. Knowing that I had an ordinary magnifying glass (that is to say, a reading glass) in the bench drawer, and jeweller's eyepiece on the shelf in front of me, I said: 'Just start counting - now.' I put the eyepiece in my eye, grabbed the glass from the drawer, and held it arm's length by the time the count had reached five. 'I have just made a telescope,'I said. This was true enough; I really had put together a simple refractor.

Another question often fired at me when I am giving talks and demonstrating my home-made 6-inch is: 'Why did you not make it with an equatorial mount?" My answer Is: "I set out to make a good, simple telescope with as few tools as possible." Of course, for prolonged serious viewing, and certainly for photography, an equatorial mounting with power drive is essential. Directly you depart from the basic pattern, however, complications set in, and the idea behind this book is to give the actual basis. There is always room for alteration and improvement if you have the necessary material, tools and skill.

I have found this out from experience, and indeed my telescopes are for ever being altered and improved. For instance, suppose that the tube sometimes gets into an awkward position; can the mounting be modified so as to remove this difficulty? Perhaps this is an easy matter; perhaps not, in which case the remedy is to leave well alone! Incidentally, I always like to use screws, so that it is easy to return to Square One. Nails and glue can be frustrating when it comes to alteration and re-assembly.

When a telescope is permanently stored outdoors, the ravages of time and weather must always be kept in mind. Grease or oil should constantly be renewed on essential moving parts, and a careful watch should be kept; the old cliché of "a stitch in time" is very true. Of course, an observatory helps immeasurably, as I will explain later.

HOW A REFLECTOR WORKS

Just in case there are any readers who do not know the principles of a reflector, I must depart from my avowed intention and say something about the way in which a reflector works (I will deliberately keep my account short). There are various optical systems. In some of them, such as the Cassegrain, the main mirror has a hole in it, or else has to be used with an extra secondary. But in the Newtonian pattern, things are simpler. The light from the object under study comes down the open-ended tube until it hits the main mirror; the light is then directed back on to the flat secondary, which sends the rays into the side of the tube, where an image is formed and is then magnified by the eyepiece. Let it be stressed that it is the main mirror which collects the light, and the eyepiece which attends to the magnification.

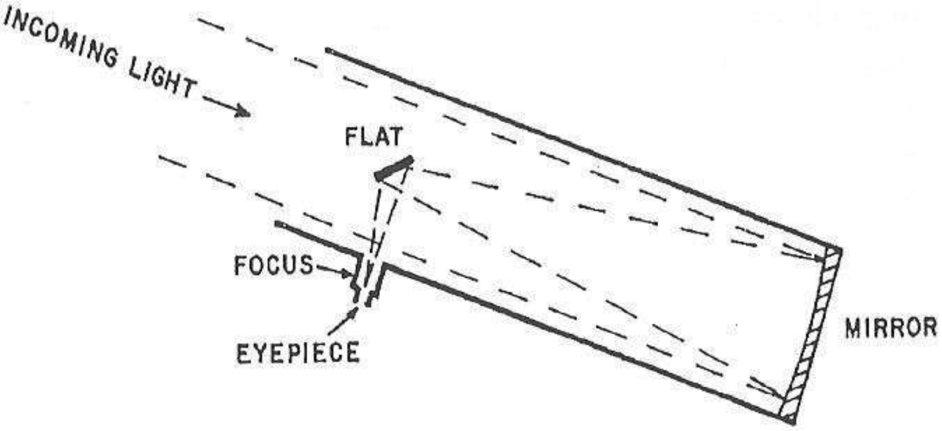


Figure 1.
RINCIPLE OF THE NEWTONIAN REFLECTOR

Changing the eyepiece alters the magnification; the shorter the focal length of the eyepiece, the greater the magnification - but, of course, the fainter the image - so that using too powerful an eyepiece will give hopeless results. In observing it is always better to have a smaller, crystal-sharp image rather than an enlarged, faint, diffuse one. Using too high a magnification is one of the worst of all pitfalls for the beginner. For my 6-inch I use three eyepieces mainly; one lower-power, one moderate, and one higher for looking at the Moon and planets on good nights.

The principle of the Newtonian reflector is shown in Figure 1. I do not propose to labour the point further, and neither do I propose to delve into other systems, mainly because to make a Cassegrain would involve rather more expense and considerably more difficulty than a Newtonian - though, of course, serious amateurs can, and do, make excellent Cassegrains.

Having "cleared the air", so to speak, let us turn to the making of my basic 6-inch. I hope that you will be encouraged to follow my example.

Making the Telescope Itself

I am assuming that anyone who is going to make a telescope similar to mine will do as I did, and purchase the mirrors from a reliable mirror-maker (in my case, incidentally, Henry Wildey of Hampstead). A 6-inch mirror will usually have a focal length of about 48 inches (see Figure 2). This is the distance that the reflected light from the main mirror (A) travels to the eyepiece (C), via the secondary mirror or flat (B). Therefore, the flat will be mounted in the tube at a little less than 48 inches from the main mirror. Adding up half the diameter of the "tube" (say 4 inches) and the eyepiece in its mounting (say 2 inches) gives about 6 inches; so the flat will be about 42 inches from the main mirror.

Perhaps you will notice already that I am giving most of the measurements as "about"! Where it pays to be more exact is in ensuring that where there are several pieces which are alike, they must be the same width and thickness. This applies, for instance, to the square frames inside the tube - and be sure that they really are square. Let me add, too, that not all 6-inch mirrors have a focal length of 48 inches, giving what is termed a focal ratio of *f*8 (that is to say, 48 divided by 6). I have come across 6-inch mirrors which are much longer in focal length, and a few which are slightly shorter.

To recapitulate: when I set out to make my telescope, at the beginning of 1975, I purchased the optics. The only other outlay was about £1.25 ($2.50) for Meccano parts for the eyepiece mount. The view-finder and eyepiece came from a broken pair of binoculars that I happened to have. Therefore the total cash expenditure was below £25, and I ended up with a very good 6-inch Newtonian reflector. Also, I used only tools of the sort that are to be found in most households - and if not, can be bought at low cost and will be useful for ever after. In fact, I spent the minimum amount of money, and used scrap materials which are by no means hard to locate.

The tube. This is to hold the mirrors, so that they can be moved in the desired direction and will keep in the same relative positions to each other. As I have said, there is no need whatsoever to have a cylindrical tube. The wonderful lunar and planetary photographs taken by Commander Henry Hatfield, from his observatory in Sevenoaks, are taken with his 12-inch reflector, the mirrors of which are mounted on a plank. I admit that it is a highly sophisticated sort of plank, but it is a plank none the less!

I decided to use two planks; actually they were two shelves that came out of the larder, and which I had had to

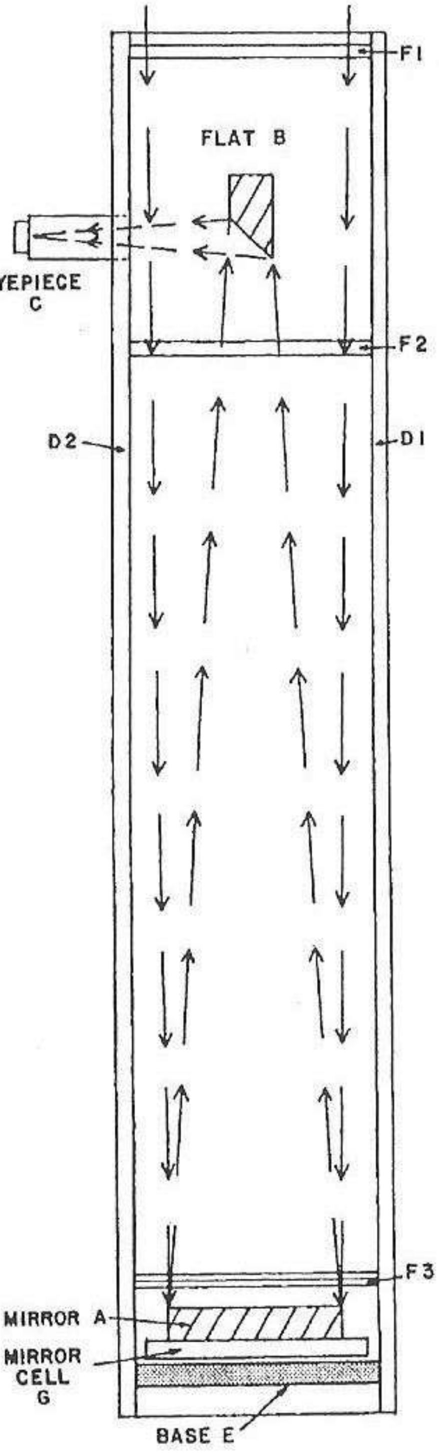


Figure 2.
CONSTRUCTION OF THE TUBE.
A, Main mirror:
B, Flat. C, Eyepiece:
& D2, Side planks for the tube:
E, Base of the tube:
1, Inner frames of the tube:
G, Mirror cell.

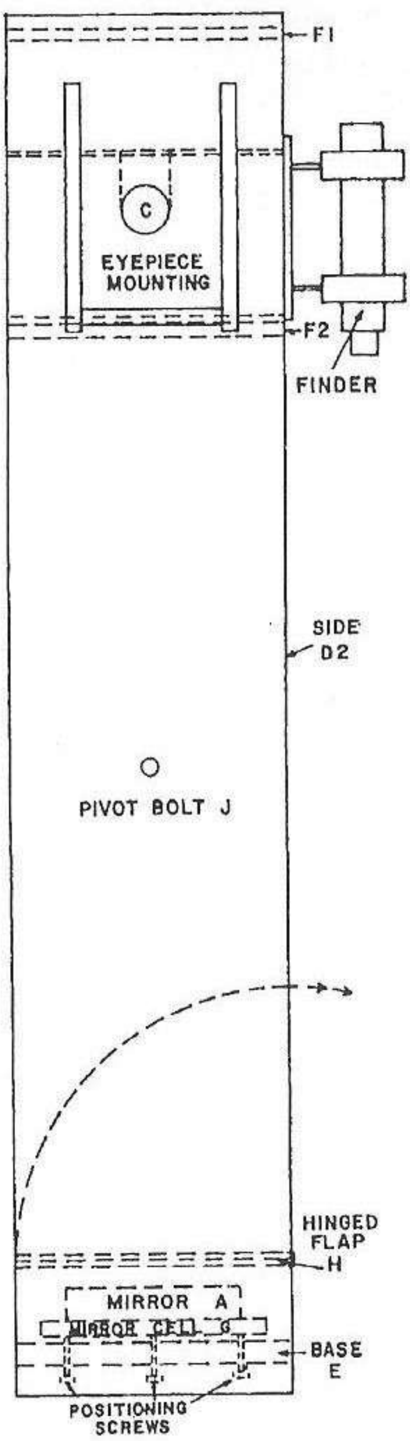


Figure 3.
SIDE DIAGRAM OF THE TUBE.
A, Main mirror:
B, Flat: C, Eyepiece:
& D2, Side planks for the tube:
E, Base of the tube:
1, Inner frames of the tube:
G, Mirror cell:
H, Hinged flap for covering main mirror:
J, Pivot bolt.

move to accommodate a new refrigerator. For a 6-inch mirror, you need the "tube" to be a little larger than this value. My shelves were a convenient 8½ inches wide. I also needed some smaller pieces to "box in" the top and bottom of the square. The upper pair were each 10 inches long, and the bottom pair 7¼ inches; the diagram will show what is meant. This is where it pays to be so careful that the widths of the pieces match. The lengths are not so critical, because the mountings of the optics can be adjusted.

Tools. The essentials are various saws. A pad saw, sometimes called a keyhole saw, cuts the circular parts. When using this, I find that the golden rule is always to cut downwards. This enables one to see that the saw is straight and cuts square; keep turning the wood, even if very slightly, and avoid cutting sideways. A tenon saw is also highly desirable. A hand saw will do, of course, but a tenon saw with finer teeth makes for a neater product. Next, one must have a wheel brace and drills (the more drills, the better), plus a screwdriver. and these were the only tools I used. Naturally, if other tools are available, well and good; it makes things easier, and helps with appearance. But I repeat that everything can be done with the basic tools I have listed. I hope that I am encouraging you to try!

Making the Tube. Now let us continue with the actual tube construction, assuming that the mirrors are of the same focal lengths as mine.

The tube is lettered D1 and D2 in Figure 2. You need two pieces of wood about 48 inches long, parallel-sided with a width of 8½ inches, and a thickness of ⁵/₈ of an inch; to box in the ends you need two pieces of 7¼ x 5 inches, and two more of 7¼ x10 inches. Assemble with screws (never nails!); here I used 1¼ x 6 inch., countersunk. Drill a clearance hole in the place through which the screw passes, and a smaller hole into which the screw can bite; this may take a little longer, but it stops the wood from splitting. (If the wood does split, a new piece has to be made, which wastes time. My motto is, 'It's quicker to go slow.')

You will probably find, as I did, that it will be necessary to undo the joints now and then; screws which are carefully put in come out easily, especially if a spot of grease is applied on first entry. (No grease? Use a piece of soap.) Throughout this procedure, be continually on the look-out for things which can be utilized. After the first attempt, it may well be that the tube does not look perfectly square. This does not matter, because the end frames will square everything up as soon as they are added.

The base of my telescope (that is to say, the unit which contains the mirror, A, and mirror cell, G; again see Figure2) is a piece Of "multi-ply", ¾-inch thick. (This came from a cabinetmaker friend of mine, who passed on to me many oddments which would otherwise be thrown away - and let me add that it also pays to cultivate people at local garages or works, who have access to scrap-heaps; you are likely to need them.) The base unit does not have to be plywood, but use it if available. Make sure that it is dry, and not liable to warp. It will be responsible for holding the main mirror firmly in place, and rigidity is of paramount importance.

Next come three frames (F1, F2, F3 in Figure 2), again of plywood if available, 7¼ inches square as with the thick base, though the frames can be thinner; mine are ³/₈ inch thick. A 6-inch or slightly larger hole is cut in each, using the pad saw. If you are not too expert at getting the circle absolutely true, there is no need for alarm, because their role is to keep the frame of the tube true and rigid, letting the light through. Performance should come first and appearance later, though of course, it is much more satisfying to make everything look neat.

The two top frames are placed so that hinged flaps can

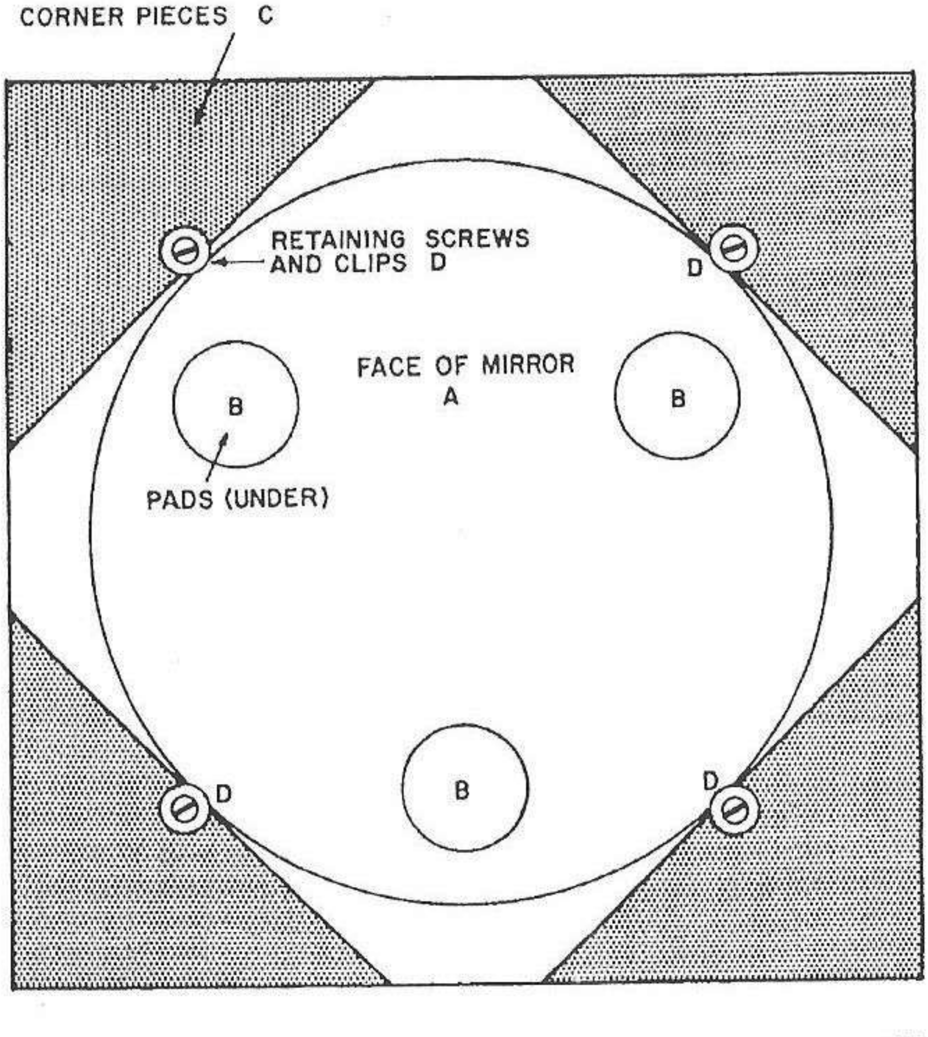


Figure 4.
PLAN VIEW OF THE MIRROR CELL.
A, Face of the mirror
Pads under the mirror
C, Corner pieces
D, Retaining screws and clips

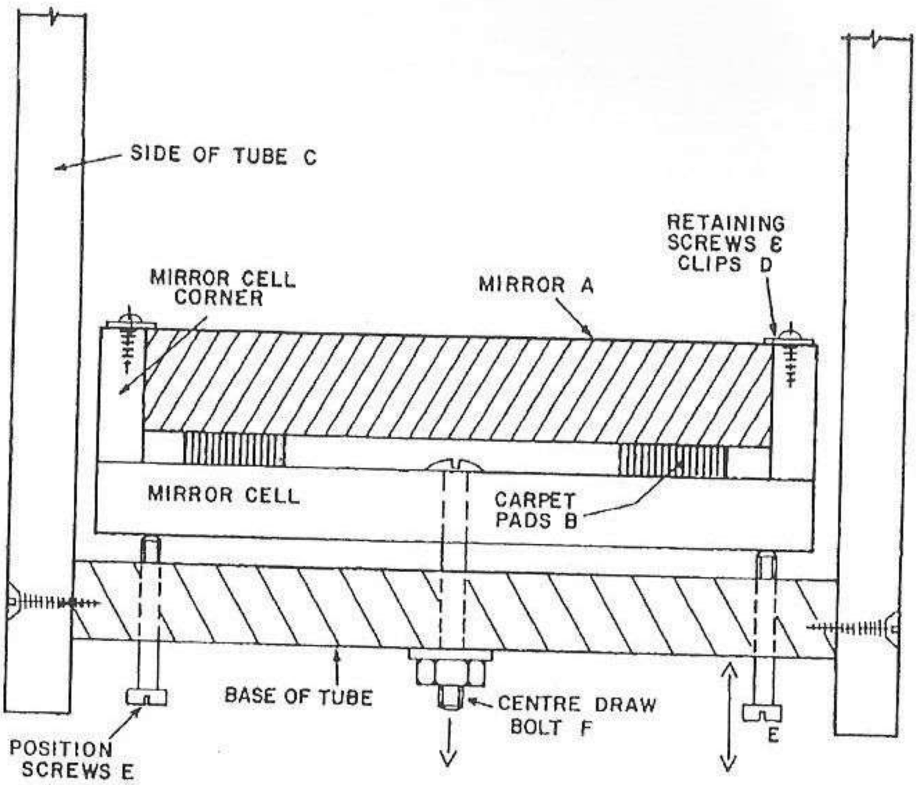


Figure 5
MIRROR CELL SECTION
A, Main mirror
B, Carpet pads
C, Sides of the tube
D, Mirror cell corne
E, Position screws
F, Centre draw-bolt

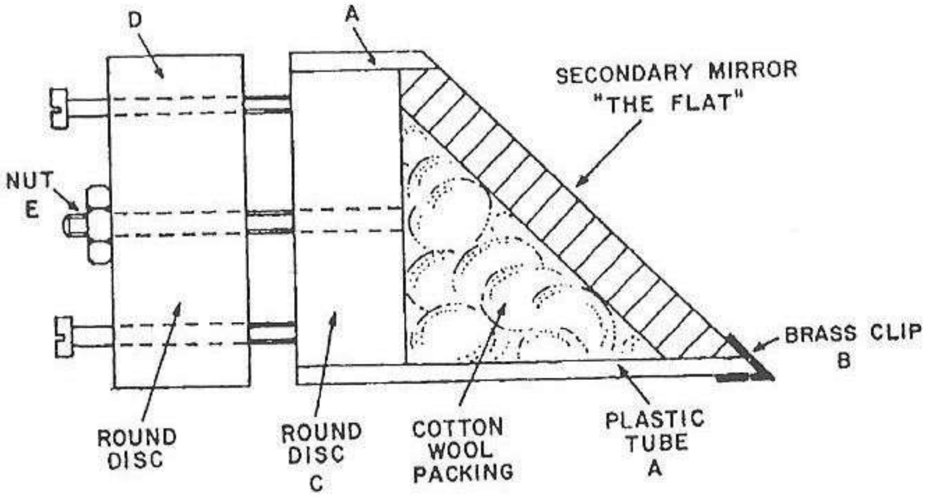
be fixed later to keep the flat protected from dust and damp (see Figure 3). The other frame is placed at the far end, so as to help cover the main mirror (H). Try to make these frames as exact as possible - all perfectly square and of the same size, so that they fit snugly into the tube and protect the mirrors as effectively as possible when the telescope is not in use. Eventually they will be painted dull matt-black so as to be non-reflective, so a little putty may be used if required.

Now for the cell of the main mirror (Figure 4). In this, mount the mirror itself, so that it can be moved by adjusting screws (E and F in Figure 5), ensuring correct alignment; this is quite a simple operation if done carefully. The mirror is held so that it does not move in the cell, though not tightly enough to pinch it, which would cause distortion. I did it as follows (see Figure 5).

I took another piece of thick ply, ¾ inch if possible, a little smaller than the inside of the tube; the inside diameter was 7¼ inches, so I allowed for about 6 7/8 inches to give clearance all *around* (Figures 4 and 5). My mirror sits on three little cushions of plushy rubber carpet about the size of the top of my thumb (B in Figures 4 and 5), equally spaced near the outer diameter (B in Figure 4). Four triangles of wood (C in Figure 4) were screwed on to the corners, with a thin piece of leather between them and the mirror, thereby preventing the mirror from shifting sideways. Four little washers (D in Figures 4 and 5) were screwed on to the edges of the triangles; these are a little less thick than the distance from the edge of the mirror to the vase. The washers just clip the edge of the mirror, preventing it from falling forward and being sufficient to hold it on to the nap of the carpet without any real pressure.

The adjustment of the mirror cell is achieved by three screws (E in Figure5) pushing in from the base, plus one from the centre of the cell (F) through the base; this pulls the base itself and holds it on to the positioning screws. The three screws in my base are 2 B.A. If the hole is drilled slightly smaller than the screw the correct size is No. 26, or 3 mm - the screw can be forced in to make its own thread. (Should you have a 2 B.A. tap, so much the better.) The pull-screw in the centre has a spring washer and nut. Adjustment of the mirrors is dealt with later; it is called collimation.

Figure 6
CTION THROUGH
FLAT HOUSING
A, PLastic tube
B, Brass clip
C, Round disk
Round mounting disk



Always - repeat, *always* - remember that the mirrors are silvered or aluminized on the surface, so that if touched by anything they will be scratched, while fingers inevitably leave damaging fingerprints. **You have been warned!** Treat them like eggs - thin-shelled ones.

Mounting the Flat (Figure 6). This can be a matter of trial and error. The flat has to be mounted in the centre of the tube, at a distance from the main mirror which brings the eyepiece to a convenient distance from the side of the tube, in accordance with the mechanics of the eyepiece mounting.

My eyepiece is about 4½ inches from the outside of the tube. The outside of the tube is 8½ inches across. Half of 8½ is 4¼. 4¼+ 4½ equals 8¾, so the centre of my flat is given as 8¾ inches less than the focal length (48 inches) from the main mirror. 8¾ from 48 comes to 39¼, so that the distance is 39¼ inches. As the eyepiece mounting should allow the draw-tube to move in and out, to allow for focusing, there should be a tolerance of an inch or so; therefore, as before, the measurements are "about . . . ."

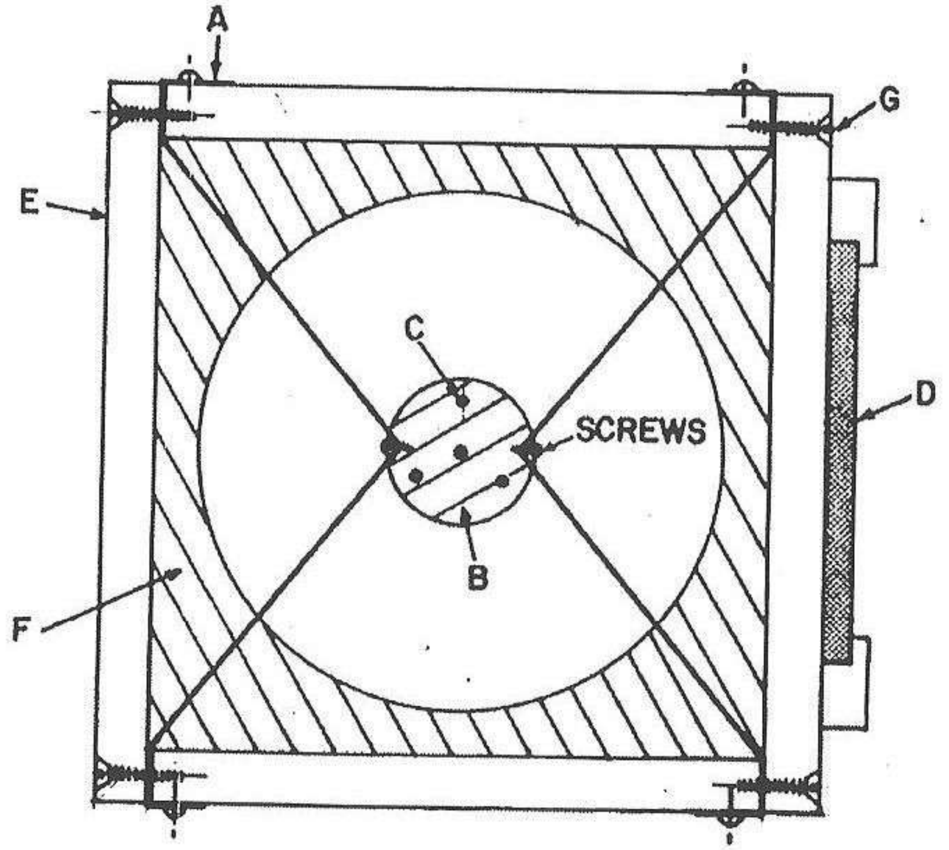


Figure 7.
END VIEW OF TU
SHOWING THE FL
A, Metal tape, pass
through sides of
B, End of Flat
C, Adjusting screw
D, Sliding board fo
focusing mount
E, Side of tube
F, Inner frame for
G, Wood screws

To make the positioning of the flat and eyepiece mounting easier, I suggest that the eyepiece mount should be made on a small piece of board - mine is 8 x 5 inches approximately ¼ or ³⁄₈ inch thick, and attached to the outside of the tube in a slide, so that it can be moved along to the correct position if the first hole has to be elongated. The board covers the elongation of the hole. The nearer the flat is to the main mirror, the further out must the eyepiece be racked from the tube.

The flat is best mounted on a piece of tube (A in Figure

6) of the same inside diameter as the minor axis of the flat. I used a piece of modern plastic pipe, as used by plumbers today. Cut off at an angle of 45 degrees, and make a small brass clip (B); the springy strip from an old cycle-lamp battery is useful. Usually the flat is about half an inch thick, and so it is only necessary to push the top of the flat from inside against the front lip to keep in place. Never stick it. At some future date the flat will need realuminizing, and to stick it is asking for trouble in advance.

Allow just enough length of tube to allow for the insertion, at the back, of a disk of wood (C) to be fixed inside for attachment purposes. The flat has to be suspended in the centre of the tube, and it is desirable to allow for the least possible obstruction of light reaching the main mirror. The flat - or, rather, its holder - is bound to stop any light from falling on to the centre of the mirror, and therefore the area at the centre of the main mirror equal to the diameter of the flat cannot be used, which is unfortunate but inevitable in the Newtonian pattern.

Flats may be mounted in several ways. If the mount depends on a single stick, then the stick must be robust; alternatively there may be two, three, or four thin blades. Nowadays most people favour four blades, and fortunately this is the easiest and simplest design (see Figure 7). I used two metal strips of the type used for binding parcels (A); the width does not matter much, because the blades are presented edgeways. The centre is screwed on to the centre of the side of another disk (B), of the same diameter as the one in the back of the tube of the flat, and about 3/8 inch thick; the ends are passed through the sides of the joins of the tube sides. In this way, the unit can easily be moved along to the correct position. Make sure that it is in the centre of the tube, and then tighten up the screws. The disk will stay quite steady, so that there is no need to pull the strips tight. The flat in the tube is attached to the disk in the same way as that in which the mirror cell was mounted, but use smaller screws, of lesser diameter; say three 4 B.A. screws pointed inwards (tapping size drill, No. 34 or 2.80 mm), and a 2 B.A. screw with nut for holding out (C in Figure 7).

Allowance should be made to have the base fitted in the tube about one inch from the end at least, so that when the telescope is stood on end the positioning screws do not project. I have weighed the tube, complete with mirrors, view-finder, eyepiece mount, and drawtube. The full weight is twenty pounds.

Let me repeat that most of my measurements are "about". This means that you can adapt any measurements according to the available material that you happen to have. If your wood is a little thicker or thinner (though it must be wide enough at the essential points), the inner measurements of the tube must be a little larger than the mirror diameter, but the thickness of the sides is not important provided that the sides do not flex or are not unreasonably heavy.

If you are lucky enough to have plenty of tools and a handy workshop, it is useful to see in which ways you can improve on my suggestions. For instance: if you happen to have a piece of brass tubing of the right size for mounting the flat, so much the better. Your view of the Moon will be exactly the same, but the telescope will look better!

As you make each piece, you will find better ideas constantly coming to you. This is why I screw everything together, so that alterations can be made. Glue is too permanent. If you are anything of a metal-worker, the mirror cell may be made to your own design. Round biscuit tins often form a basic source for ideas, for instance.

When the tube has been completed, with its focusing mount, view-finder, eyepieces, and everything that will be attached to it when in use, roll it backwards and forwards on a piece of rod or tube on the bench or table to find the point of balance, and then mark the sides, for projections to be attached to it in order that it can sling in the V's of the fork mounting. I used two short 1/8-inch bolts through the sides, because they happened to be handy and were of the right length.

So much, then, for the telescope itself.

View-Finders

The fainter a star is, the greater the need for a view-finder to locate it. Most finders are nothing more than small refracting telescopes; the finder is mounted on the side of the main instrument (Figure 8), so that when the required

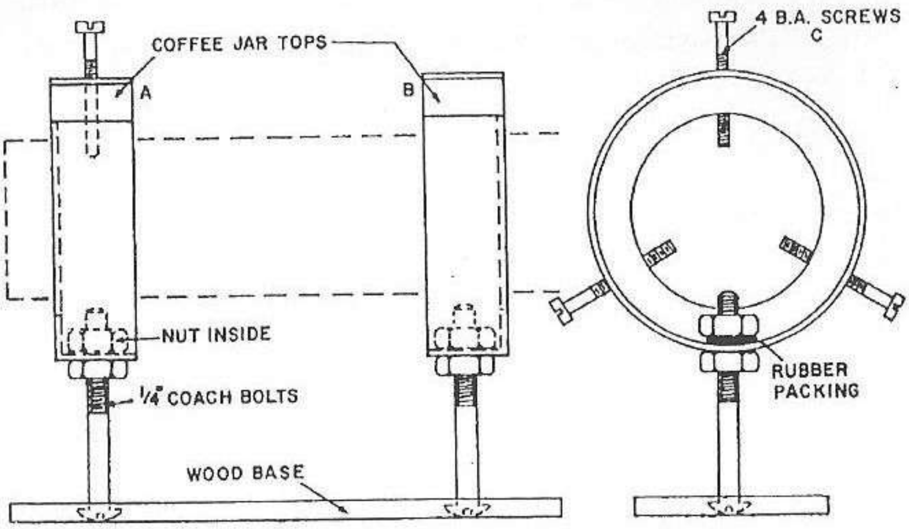


Figure 8.
SECTION OF
FINDER MOUNT
d B, Coffee-jar tops
C, Screws

star or other object is located and put exactly in the centre of the finder field, it will also be on view in the eyepiece of the main telescope. The finder is usually set in two rings (A, B) with screws which can always be re-adjusted if necessary. As you will see from the diagram, the rings can easily be made from my usual (or unusual) odds and ends - in this case I used the tops of coffee jars. The actual finder was made from the optics of an old pair of binoculars that I happened to have. I realize that it is unlikely you will find old binoculars lying around, but other ways can be found. for instance, I think that one of the children's telescopes sold in toyshops could be used. I have not actually tried one, but it seems reasonable. I did experiment with a small magnifying glass and a jeweller's eyepiece. I admit that there was a great deal of unwanted false colour, but the method worked.

On the first time when I tried out my telescope, there was a beautiful star-studded sky, and Orion was just asking to be looked at. I had not yet fitted a finder, and I was anxious to see what sort of image the telescope would give. By merely looking along the top edge, which you can do with a square tube, I sighted the telescope on the "Sword", and when I looked in the eyepiece there was the Great Nebula, M42, with the wonderful Trapezium in all its glory - one of the many highlights which one never tires of seeing again and again. That was without the aid of afinder; and if finance is a problem, there are always refinements which can be left out. On the other hand, there is no doubt whatsoever that a finder makes things much easier, and it is a pity not to have one. Another simple method is to mount a couple of projections on the tube, in the manner of gunsights. This again is nothing more than a matter of common sense.

The Tripod Mount

A telescope mount cannot be too rigid and substantial. It has been said that in making one, decide on the construction, work out the maximum weight you can possibly need, and then multiply by three! Of course, weight has to be considered if the stand is to be portable, and we have to balance rigidity against sheer weight. My own telescope mount weighs 15 pounds.

The stand (Figure 9) is made up of three legs, each 2 feet 9 inches long, and each 3 x 2 inches. They are screwed firmly on to a round disk, 8 inches in diameter, made of ¾ inch ply (B) at the top, and splayed to 1 foot 10 inches at the base. They are secured to a triangular shelf about 1 foot from the floor, through which the vertical shaft passes to its bottom bearing. It so happened that there were some spare lengths of 3 x 2 inches left around after I had built my observatory - which had been made from an old garden shed that had seen better days.

To attach the legs firmly to the round top, I used small fillets of 2 x 1 inch (D), so that the screws did not go into the end grain. I screwed the top down into the fillet, and then screwed through the side into the top of the leg.

An altazimuth mounting needs a vertical shaft, and for amateur construction I have never found anything better, handier, and easier to obtain than the half-shaft of an old car (E). By using one of these, there is no need to worry about bearings; they are already there. A large ball-race at the thick end (F), just where it is needed, complete with disk with bolts and nuts, is ideal for having a telescope fork mount attached to it. The thin end has a countersunk hole, just right for a pointed screw to hold it captive and prevent any lateral movement; there is also perfect freedom to rotate (H). Actually, "rotate" is the wrong word, since it indicates a movement of spinning round and round, whereas what is needed is for it to radius slowly about its axis without wob-

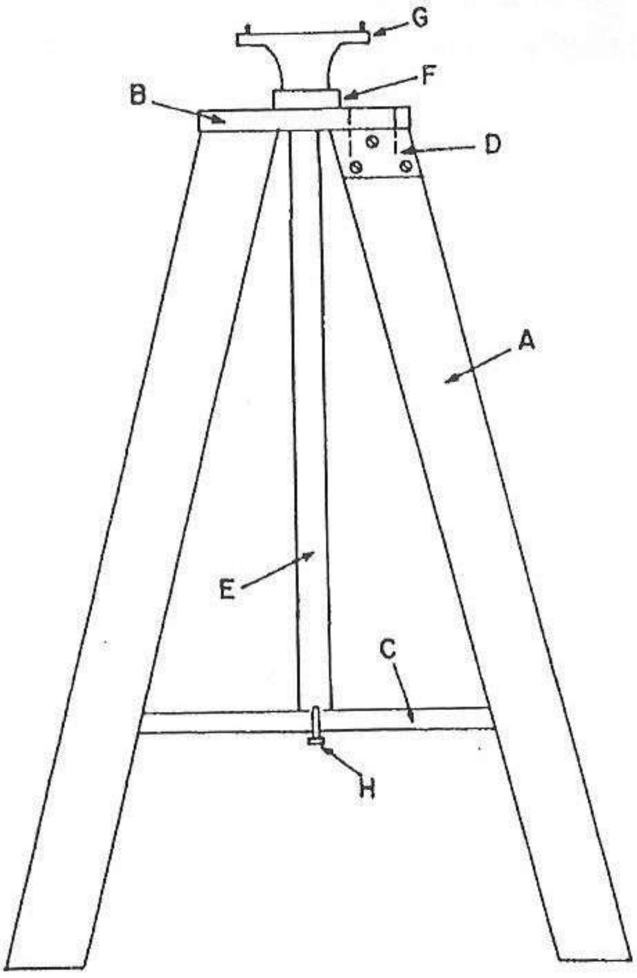


Figure 9.
TRIPOD
, Legs: B, Top Disk
C, Lower shelf:
D, Wood fillets
E, Half-shaft:
F, Ball-race
G, Mounting disks
, Positioning screw

ble. This it will do to perfection, if it is carefully mounted and is fitted with a slow-motion control of the type to be described later.

A centre shelf (C) is needed to hold the bottom sections of the legs firmly in place, situated so that a pointed screw (H) can project from the underside to engage the countersunk hole in the end of the half-shaft, mentioned above. As the shaft hangs from the top with the ball-race resting on the tripod head, it ends where the shelf is fixed. There are various ways of making it. I used six pieces of batten, 1 x ½ inch, screwed to the sides of the main legs, centring on to the piece with the pointed screw holding the shaft. Cross-braces can also be attached if wanted. Everything is hidden by a piece of hardboard at the top, convenient for taking spare eyepieces or other "bits and pieces"; a small rail round it can stop eyepieces rolling off in the dark. (It is also somewhere to put a torch. A red light upsets one's dark adaptation less than a white one.)

It is true that the legs of my tripod are on the heavy side;

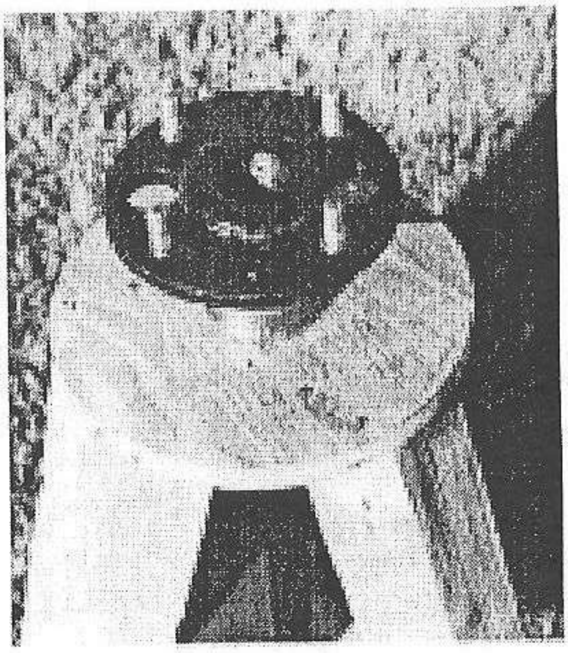
but they are firm, and I have no difficulty in carrying the tripod around, usually to put into the boot of my car! If you use less robust materials, make sure that the braces are really firm.

When I demonstrated my first tripod at a meeting in Worthing, Henry Wildey, the telescope maker, asked why the tripod was so high. This was something which had not occurred to me. It seemed about right; it went easily into the car boot, and as I normally concentrate upon observing the Moon and planets the height did not worry me. However, I sawed off about three inches from the bottoms of the legs, and left it at that. Some time later I wanted to look at an object directly overhead (so far as I recall, it was the Ring Nebula in Lyra), and with the tube in a truly vertical position the eyepiece was too high for me to reach. I fetched something upon which to stand; it was only an inch or two high, but after a few minutes I stumbled. This made me decide upon further action. I set the telescope up with the tube in a vertical position, checked to see how much would have to be cut off so that the eyepiece was level with my eye, and removed another two inches from each leg. Now, whenever I use the telescope, both my feet are planted firmly on the ground. If the object is low, I bend down or even sit down. The more comfortable you are when viewing, the more relaxed you will be, and better observations will result.

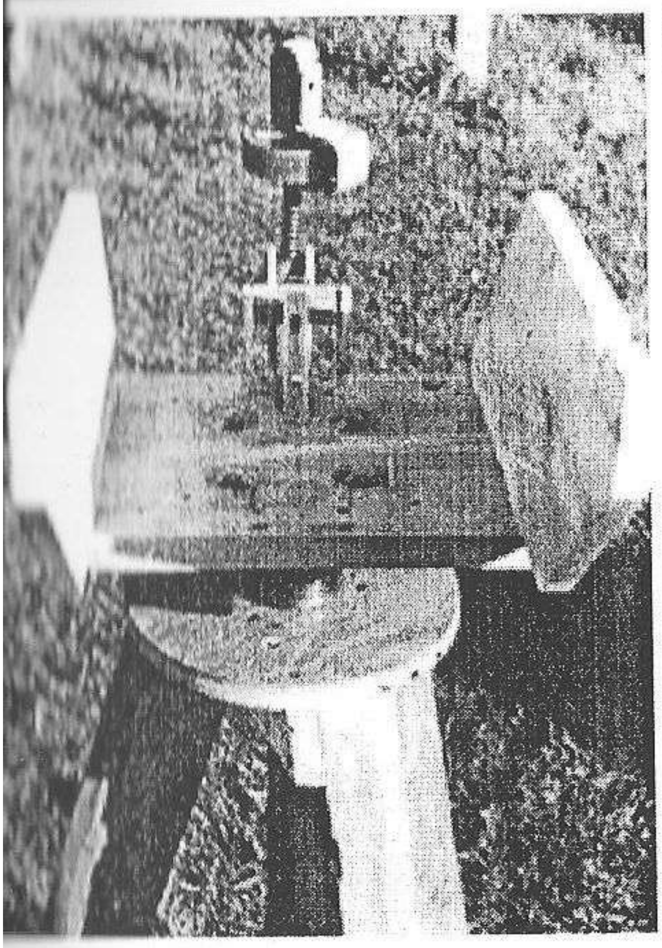
At the moment the eyepiece is 5 feet 2 inches from the ground when set up vertically. This suits me, as I am fairly short (5 feet 4 inches). A taller person can always bend down, but if I am letting a boy or girl look through the telescope, and some extra height is needed, I am always careful to make sure that the "step" is substantial.

Remember, most observing is carried out in pitch darkness, and things are not always where you expect them to be. When you cannot reach the eyepiece, and want something upon which to stand, it is surprising how little height is needed. A six-inch footstool is ideal, with an extra one-inch piece of wood if necessary. I suggest avoiding any stool with appreciable legs. On the whole, I recommend an assortment of thick pieces of board. Always avoid having your first accident!

The tube and tripod mount



Top of the tripod



Top of the tripod, and fork

The Fork for the Tripod

Having made the tripod, the next need is for the fork to carry the telescope itself. This is made from a flat piece of wood, "multi-ply" or marine ply if available, around 3¼ inch thick. If you have a piece of oak or mahogany for the base and the two sides, so much the better. The dimensions are, needless to say tailored to suit the tube you have made; give half an inch clearance at each side and at the bottom when the tube is lying in a horizontal position. The sides must project backwards, so that the V cuts allow the tube to swing to the vertical and clear the tripod legs (the legs themselves, not the gaps between). Otherwise, the tube will hit the legs when it is being moved around. A little trial and error is called for here, and try everything out carefully before making the final cut with the saw. When making the V cuts, do so with the two sides held firmly together so that the tube is kept central. For this purpose, screws set carefully in the base of the V cuts allow the tube to be very delicately adjusted, as the diagram shows (Figure 10).

A bridge of metal or wood can be fixed across the V, with adjustable screws if needed. These are not to hold the tube in, but to act as a brake, so that the tube can move evenly in declination without any backlash. The whole object of the stand is to allow the tube to move smoothly in

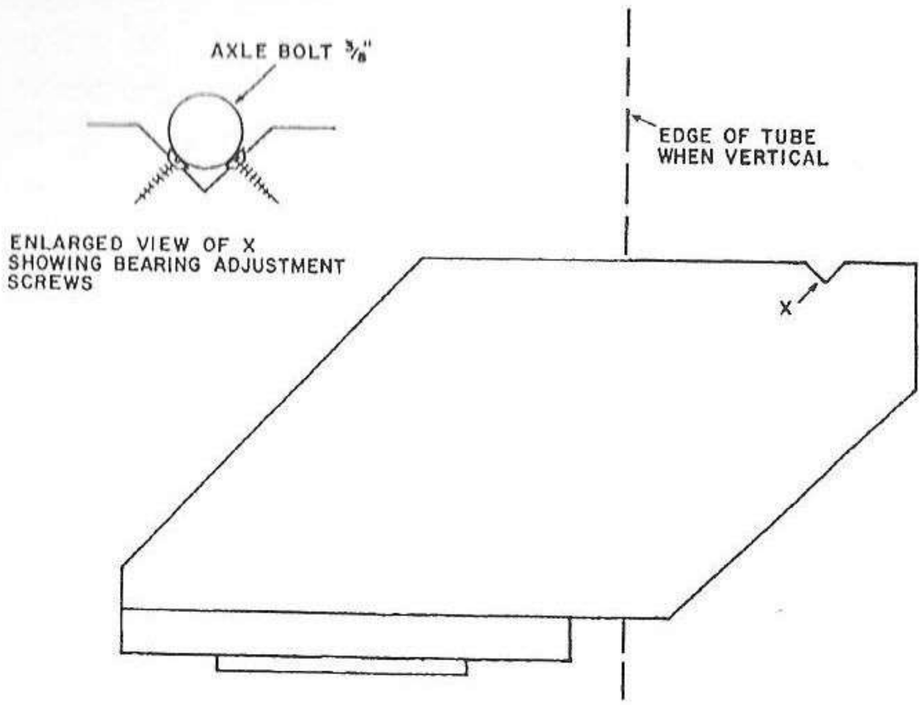

AXLE BOLT 3/8"
EDGE OF TUBE WHEN VERTICAL
ENLARGED VIEW OF X SHOWING BEARING ADJUSTMENT SCREWS
X

Figure 10.
SIDE OF THE CR

each direction, with as little rock or wobble as possible - a point which should always be borne in mind during the construction.

The fork as I have made it consists of a base with two sides screwed from underneath. Of course, if you want anything more substantial, use any available materials and make amendments accordingly. The whole idea of this book is to show what I have done with the minimum of tools and materials; this is why I recommend using screws, so that alterations can be made at any time.

A look at a friend's telescope, an article in a magazine, or even at something far removed from matters astronomical - for instance, a farm instrument which may have a useful mechanical movement - can always spark off new ideas. Parts of my telescope came from a car; is there anything else that could come from that direction? I doubt whether a speedometer would help, but you never know! When developing motorized improvements, windscreen wiper motors are sometimes very useful for a drive override, especially if the motor is fitted with a reversing switch.

Slow Motions

Having made the tube and the fork, and with both sitting nicely on the top of the car axle mounted on the tripod, the next need was movement control. As the telescope has to be pointed easily to any part of the sky, and stay there until some slight movement is necessary to see another part of the moon or to track a star or planet, mechanical movements became involved; and having allowed myself only four tools in the whole construction, this required some careful thought. The means of pointing the telescope up and down, from the horizontal to the vertical (90 degrees), and/or also moving from left to right or right to left over the entire 360 degrees, seemed something of a problem at first, though ideas soon took form.

In my opinion, it is more important to give a slow-motion device for up and down movement (declination) than for sideways movement (right ascension). The latter can be done by cautious hand pushing, but declination is different.

I decided to make a start with an old carjack, 18 inches long (A) with a nut (B) that had a swivel mounting (see Figure 11).

When a rod is screwed out from its nut, it wants to go in one direction only - straight out; but as ours will be attached to the top end of the telescope tube (C), that end will need to describe part of the radius of a circle as it moves up or down. This means that the nut must be free to swing slightly when in operation. Yet if we want to go from the horizontal to the vertical fairly quickly, screwing down would become tedious, particularly if the reverse motion is required soon afterwards. The need is to incorporate a quick motion with the slow.

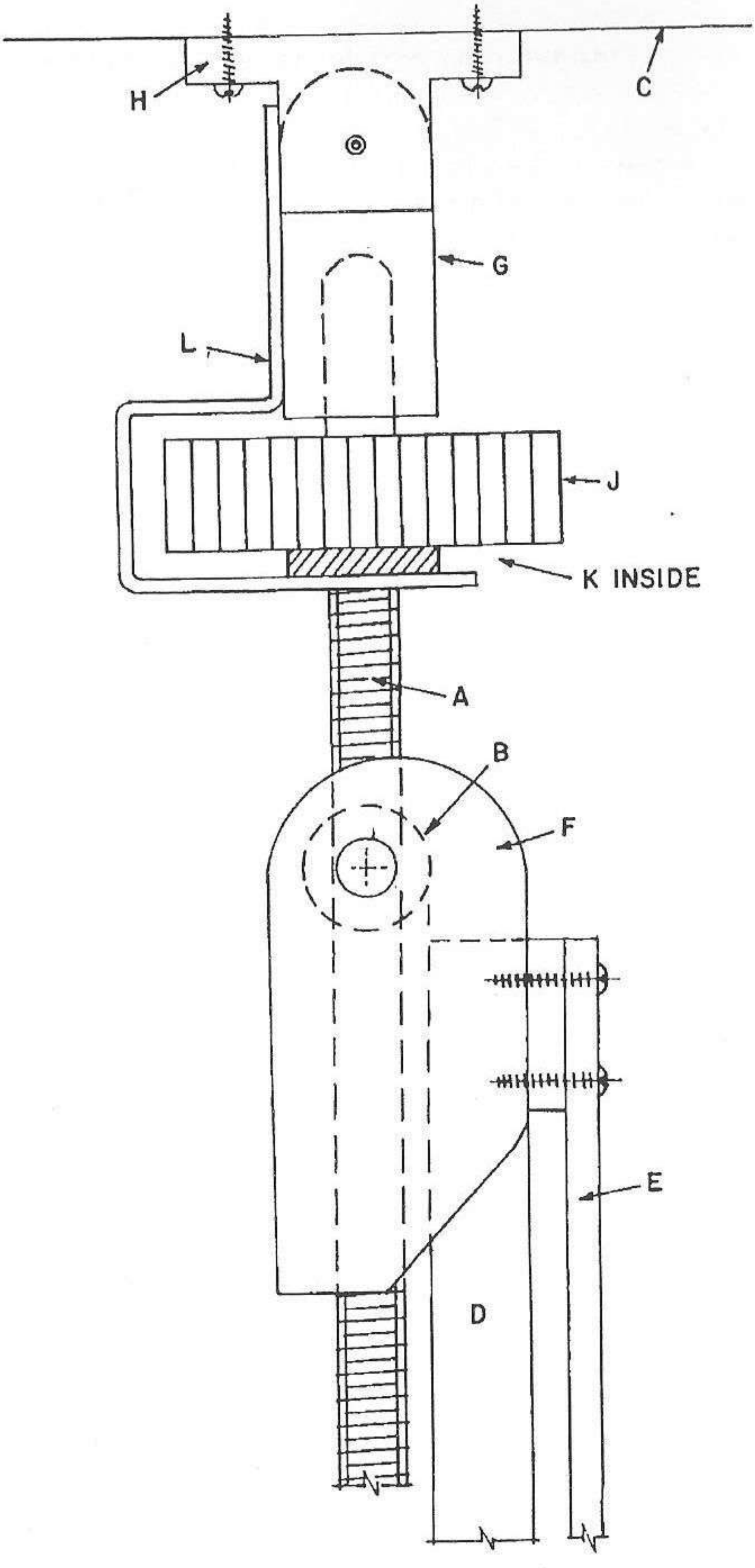
Two pieces of marine ply were shaped to project downwards (see Figure 12) from the front of the fork mount (A) at the appropriate angle, so that a piece of square section wooden rod, ¾ x ¾ x 18 inches long, would slide up and down between them and be clamped at the appropriate place with a butterfly nut (B).

The jack screw could then take over for the slow motion. I incorporated a back strip (E) to keep the wooden rod from wandering away from the clamp screw. The metal jack nut was then housed in a small wooden cage (F) at the top of the wooden rod, so that it was free to swivel as required. It looked a little clumsy but remember, I was limited to four tools! When in use, an occasional adjustment to keep the nut somewhere in the approximate centre of the jack screw avoids frustration at a critical moment when observing.

Attaching the end of the screw rod to the end of the tube is something that does, I am afraid, look rather ajumble if not done mechanically, but it works, which is the main thing, and everyone will have his own ideas; for instance, an old ball and socket joint would be useful. In my case, the fixing was done by a small block (G), 1¹/₈ x ¹/₈ x 2½ inches long, swinging easily between two blocks (H) on the underside of the tube, giving the minimum of "play". A hole was bored part of the way into the block to take the end of the screw. Obviously the tube cannot descend further than the rod will allow, but it will not keep the tube down if overbalanced by the mirror end, so that it has to be kept captive.

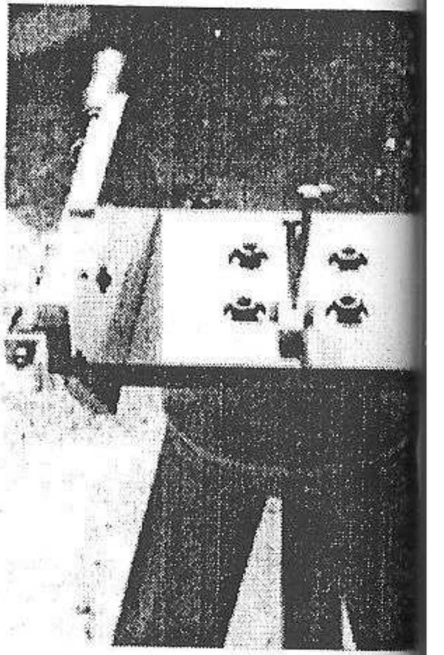
I had arranged a hand wheel, by using the plastic top of a coffee jar (J in Figure 11) and clamping two pieces of wood

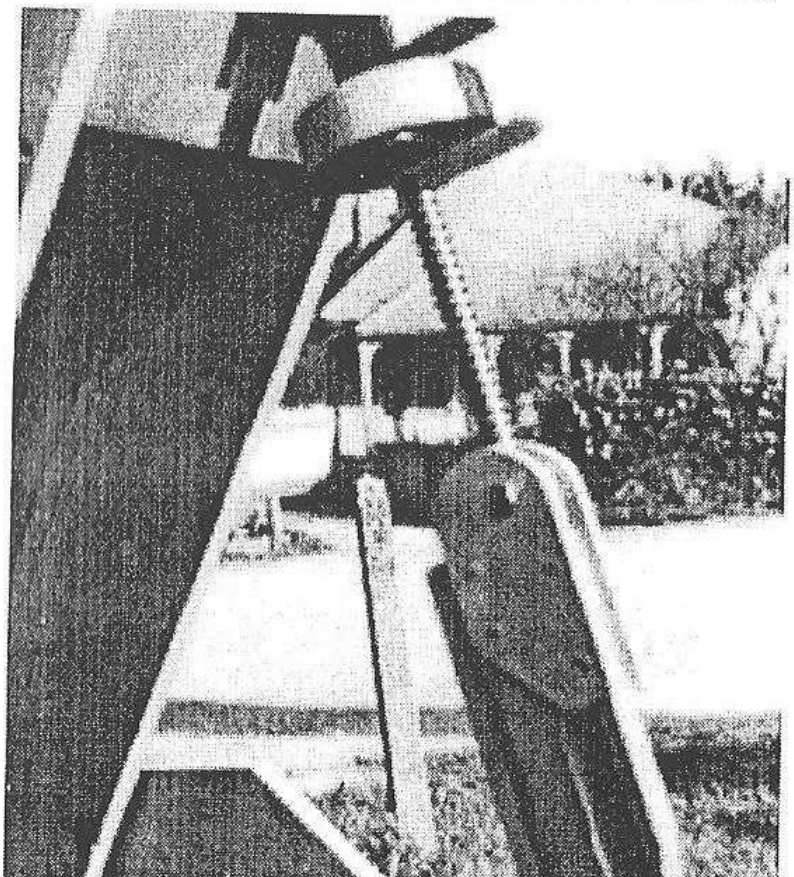
Figure 11.
DECLINATION FITTING.
A, Car jack screw:
, Nut of this car jack screw:
nderside of the tube:
D and E, Sliding bar:
F, Nut cage:
, Housing for screw:
H, Pivot for G:
J, Coffee-jar top:
K, Clamp inside cap:
L, Aluminium strip.



Declination assembly

Fork mounting - Mark 2





Declination details

(K) around the screw, screwing down through the jar caps into the clamps. The serrated edge on the outside was ideal for fine "tuning". A piece of aluminium strip (L in Figure 11) was bent to the appropriate shape to keep everything where I wanted it. This dealt with the up and down motions. Sideways movement came next.

The telescope moved beautifully on its car axle mounting, with no wobble, but when observing very slight motions are required. A worm and pinion is ideal for slow, controlled turning, but is not easily available, and is very expensive to buy. I was lucky with my first telescope; a friend gave me part of an ex-army gun rangefinder fitment, which had an enclosed worm and pinion gear override, and my tube and fork could be mounted upon that. Unfortunately, there are not many ex-army fitments left now.

What could be done, then? Suppose that a $^3/_8$ inch or ½ inch Whitworth bolt could be mounted so that its screw thread would be spring-pressurized against the round top of the tripod: would that be sufficient hold for it to be moved around? I tried it and it worked well. So another wooden cage (C in Figure 12) was made to fit over the two extending arms, pivoted so that the thread of the screw (D) was pushed against the tripod head by a spring (E), held with lock-nuts so that there was little or no side-play. A hand

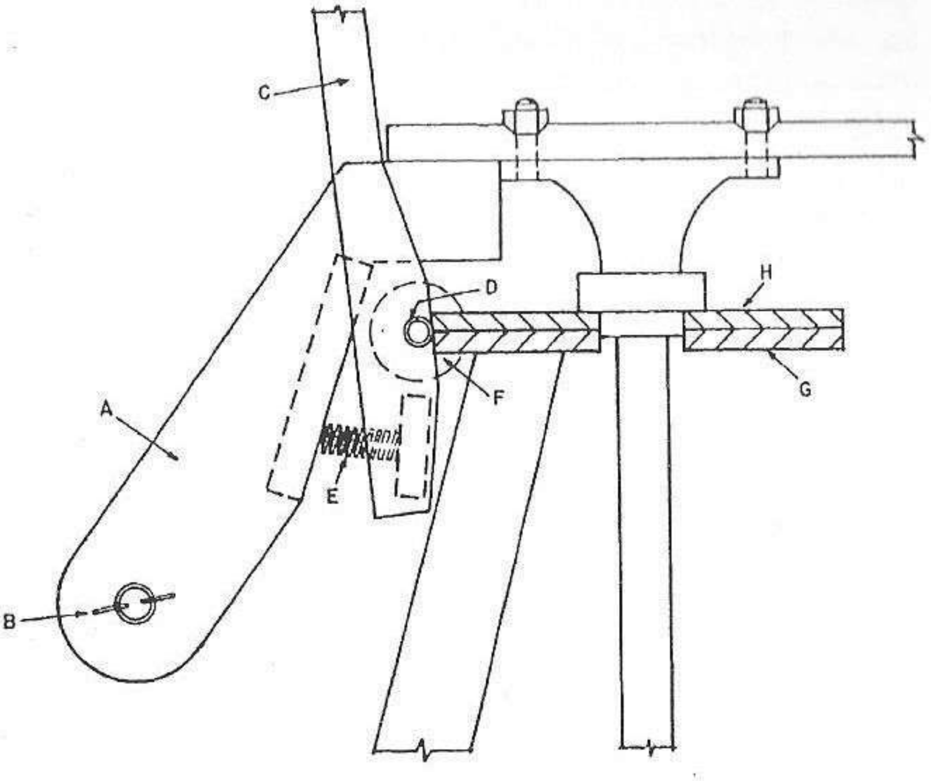


Figure 12.
POD TOP SECTION.
A, Strut: B, Wing-nut:
C, Worm-screw cage:
D, Screwed rod:
pring: F, Hand-wheel:
G, Top of the tripod:
H, Friction disk.

wheel (F) was fitted, and all seemed well.

This was my first slow motion. It worked, but it was probably the weakest part of the telescope - inevitable when only four tools could be used. Later I made something better, which I will describe next.

Optional Improvements

With a home-made telescope, constructed from odds and ends, there is almost always room for improvement. So far I have kept everything as simple as possible, assuming that only the four basic tools were available; but if you have more, there is plenty that can be done. Here are some of the improvements I have made. Perhaps you would like to try some or all of them.

One disadvantage about the original telescope was that to move the tube quickly sideways, it was necessary to release the threaded screw from the top of the tripod by releasing the spring pressure. This meant pressing the bottom of the small cage outwards until the approximate position was reached, and then re-engaging. It struck me that constant easy movement, held by friction alone, would be a great help.

The weight of the tube and half-shaft was 30 pounds. A disk of plywood, the same size as the top of the tripod (8 inches in diameter), half an inch thick, was made; the central hole was equal to the diameter of the shaft just under the ballrace, so that no side play was introduced when the screwed rod operated on the new disk. The weight of the shaft and tube was sufficient to hold it in place. Tension could be adjusted by the pointed screw under the bottom shelf where the half-shaft ended. It worked excellently. The edge of the disk was also slightly hollowed to give a better surface to the screw thread, though I doubt whether this really mattered. I then re-housed the screw in a metal box, with tension springs for neatness.

Looking for these things in my scrap box, I noticed a pinion-wheel about 4 inches in diameter, together with a wormwheel I had made for it. (It had been part of a home-madeconcrete mixer.) This seemed to be ideal for a slow motion in declination, so I started to experiment. It would mean a metal bearing on each side, capped so that there could be no up or down movement, plus a firm connection from the axis and the tube and pinion wheel. This was naturally a machine-shop task. Luckily, I had some suitable pieces of.aluminium to make the bearings.

A piece of steel, ¼ inch diameter (A in Figure 13) was machined, and welded on to a steel plate (B), 9 x 4 x ⅛ inches (the exact size was immaterial). A brass disk (C) was brazed on to the shaft 1¼ inches away, to form the friction clutch rubbing against the pinion-wheel. The shaft was reduced to ⅜ inch, and threaded to take a spring and tension nut (D) for adjustment of compression. The worm wheel (E) was housed on the side of the fork, so that the pinion-wheel was in correct contact when lying in the bearing. By lifting the top halves of the bearings, it could easily be lifted out when the telescope had to be moved. I made the holding-down screws of the pinion bearing extra long, to avoid loss, so that spanners would not be needed. A short control rod with a Hooke's (universal) Joint lies in a rest along the fork side, convenient for use. As these two controls move with the tube, they are always in the same place when observing is being carried out, whatever the angle or direction. (The controls of an equatorial mounting are notorious for not being where they are wanted during observing time!)

Next there is the all-important question of the eyepiece mounting. This is absolutely vital, because when observations are being made one must adjust for a correct focus -

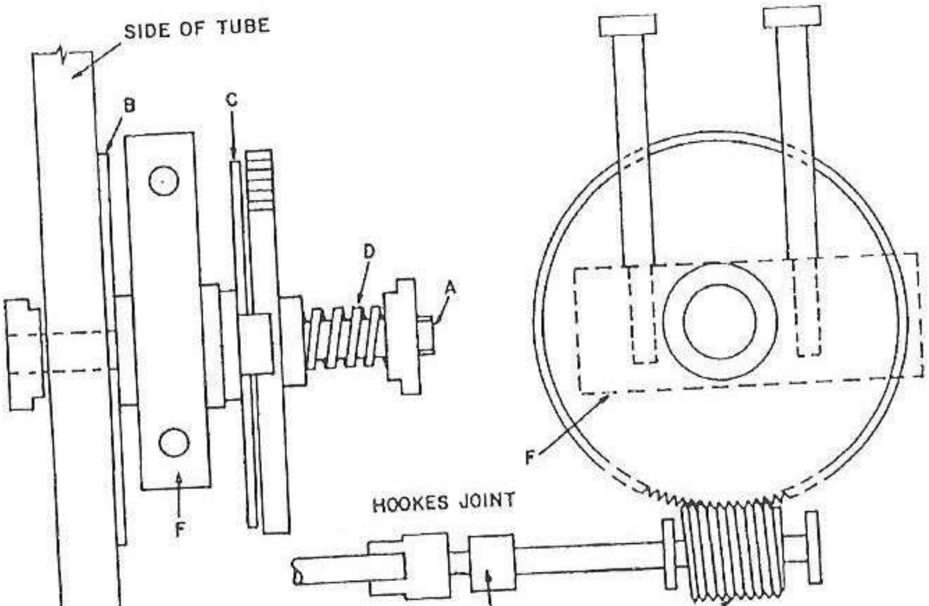


Figure 13.
WORM AND PINION FOR DECLINATION SLOW MOTION
A, 1/8-inch bolt: B, Side plate: C, Brass disk: D, Tension spring: E, Worm-wheel: F, Side bearing: G, Hooke's joint.

and it is surprising how a little adjustment can sharpen up the image. The simplest eyepiece mounting consists of one tube sliding smoothly inside another. This can be made in various ways - by using cardboard tubes, plastic water-pipe, or (if available) brass or aluminium tubing. The rack and pinion mount fitted to almost all professionally made telescopes is difficult to make, and is expensive to buy.

My ideal is the "Crayford" eyepiece, designed by John Wall. My first Crayford was made with *Meccano* parts (which, incidentally, accounted for the initial small cash outlay). I used one plate of 2½ x 1½ inches, two 2½-inch strips, four small angle pieces of ½ x ½ inch, five 1-inch grooved wheels with rubber tyres, two springs and four pieces of rod, plus two spring clips with four nuts and bolts. Figure 13 shows the basic idea of the mounting. I hope the pictures of the *Meccano* mounting will give you the idea of how I made mine.

Further Modification

Subsequently I decided to modify it, though keeping more or less to the original design. A short piece of square aluminium bar, 1 x 1 x 1¾ inches long, has four small ball-races (B in Figure 14), each ½ inch in diameter, mounted on stalks ¹/₈ inch high, to resemble a 'V' engine. The eyepiece tube (A) rests on these; they are set at 90 degrees, and are spaced so that the tube touches the exact centre of the sides of the ball-races. The end of this short bar is attached by screws passing through a disk (F) of 4½ inches outside diameter, so that the tube resting on the ball-races passes easily through the centre hole in the disk. In my case, the hole is a fraction over the 1½-inch diameter of my eyepiece tubes. A short piece of aluminium, channel section (G) is hinged above, so that a ³/₁₆-inch rod (D), passed through the channel section between the ball-races, is pressed down on the eyepiece tube, so that when the rod is rotated ihe eyepiece is focused. Pressure on the tube by springs can be effected by tension springs tucked inside the sides of the channel or, as in the first one that I made, a compression spring on the top. With an altazimuth mounting, the draw-tube holding the eyepiece always moves back and forth horizontally. With an equatorial mount which may have a rotating tube, it is often far off the horizontal, so that if the spring pressure is not too strong there is little tendency for the eyepiece to drop out. I do not think that the Crayford, unless very well made, would be so suitable for a refractor, since one looks *up* a refractor instead of *in* as with a Newtonian reflector.

By altering the declination movement to worm and pinion, the wooden projection from the front of the fork mounting that held the screw from the car jack was no longer needed. As this also held the screw that turned the tube round in right ascension, the threaded screw was re-housed in a small box arrangement of pieces from the aluminium scrap store. I used some pieces of channel section 2¼ x 1 inch, and two odd bars, so that the threaded rod was able to radius slightly inwards, pulled by a spring (or springs) exactly 3 inches below the bottom of the fork mount, so that it would bear on the centre of the top friction disk of the tripod top. This is shown in the diagram - though do not copy my measurements unless your distances are exactly the same. (Finding the right distances and tight spring tensions calls for much thought, but it is all good practice, and a second look in the scrap box can often bring to light something even more suitable.)

For this improved "Mark 2" slow-motion drive I chose a piece of ½-inch diameter Whitworth thread rod that had a newish sharp-edged thread to help bite into the wood. I turned little shoulders on the bar to keep it from moving sideways in the housing, while retaining freedom of movement; remember that the essential is to combine rigidity with

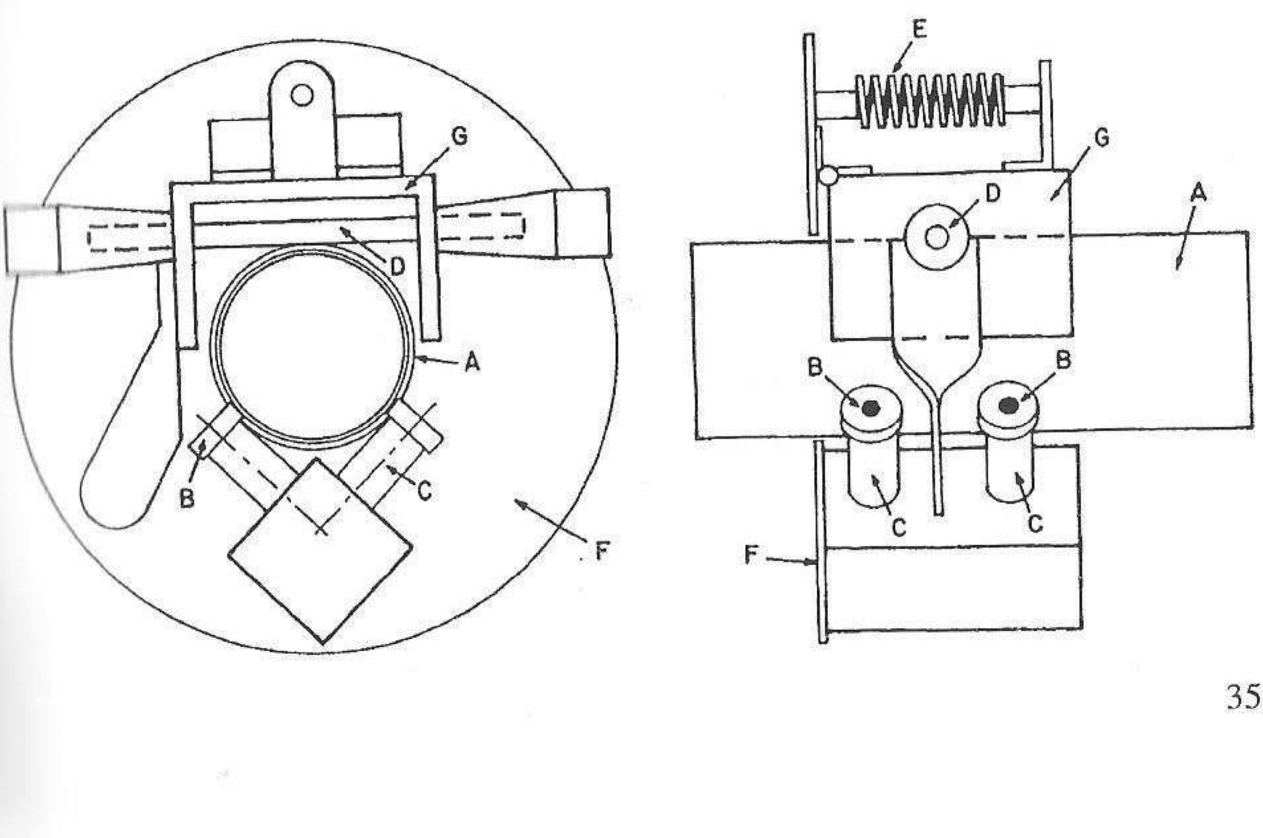


Figure 14.
CRAYFORD EYEPIECE MOUNTING
A, Draw-tube: B, Ball-races: C, Studs: D, Movable rod: E, Spring: F, Disk:: G, Rod bearing.

smoothness.

Having used the optics from the old binoculars for my view-finder, I thought it would be useful to make an elbow finder with one of the prisms and the other two lenses. I used two pieces of wood. One, sloping at 45 degrees, had the prism held to it by a cardboard frame, with the object-glass and eyepiece held in pieces of plastic tube. Insulating tape was used to pad out where necessary, and by moving the components to the required focal lengths I found that the arrangement worked. Pieces of hardboard on the sides kept the tubes in place, and a new view-finder was born. My idea was that by having one finder close to the eyepiece, the observer has only to move his head an inch or so to the right to correct for alignment, instead of having to move one's entire body or even lean over the top of the tube. To find a star or planet in the first place, I find it easier to use a finder pointing in the same direction as the tube, but the elbow finder is a nice extra. I have since mounted the optics In metal tube and housing. This does not work any better, but it looks nicer, and it was something to do on a wet Sunday afternoon!

Observatories

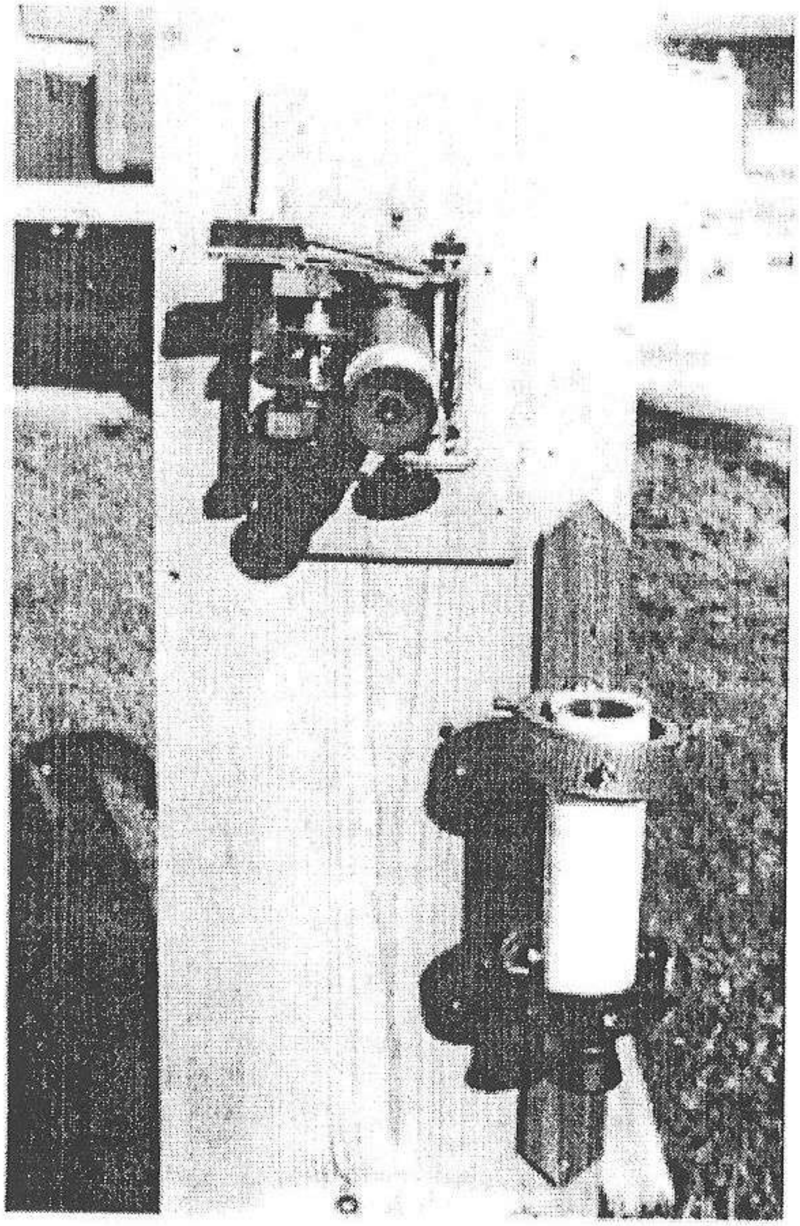
When one has acquired a telescope, the next question is, usually: Where shall it be kept? If stored indoors, it has to be carried out every time it is to be used, as viewing from an open window is hopelessly restricted, and there is also the problem of warm air-currents circulating to spoil the image. This leaves only the great outdoors - in fact the garden, if you have one. I am lucky in living in the country, with a large garden and a wide range of northern and southern aspect, at Selsey in Sussex. The reasonable definition of an "observatory" is a permanent building, from which astronomical phenomena may be observed telescopically. If something of the kind can be erected in your garden, then the main considerations are type, size and cost, with cost usually heading the list.

My retirement in 1971 provided the opportunity to attend many meetings of the British Astronomical Association (both the ordinary meetings in London and the Lunar Section gatherings, often held in the provinces), as well as to accept the many kind invitations to view fellow members' telescopes and observatories. Therefore, before describing how I solved the problem for my own needs, it may be useful to say a little about the various amateur observatories I have seen.

One of the best in my experience is that owned by Terry Byatt at Moulton, near Spalding in Lincolnshire. There is a circular wall of breeze blocks, with a revolving hemispherical dome of marine plywood ribs and hardboard, all excellently designed and made.

The cheapest and most effecient housing for a permanently sited telescope is, I suppose, the run-off shed (I am not sure whether it can be called an observatory!). In my own home village of Selsey, Patrick Moore has a shed of this kind over his 12½-inch altazimuth reflector. It consists of two three-sided boxes, roofed, and sliding away from each other on rails. They are about five feet high, and each has four grooved wheels which run on rails, set in concrete about 2 feet apart. Flat wheels running in angle iron (old bedstead sides?) would do almost as well. Undo a simple hook catch, pull the two boxes apart, and the telescope is ready for use. The whole shed was made a quarter of a century ago, and is constructed of 2 x 2-inch framing with weatherboard sides and roofing felt on top; it is still as good as when first made, and I have been using it myself for the past ten years with never the slightest trouble in opening or closing it. A run-off shed of this kind is easy to construct; provided that the framework is rigid, the shed itself could be made of hardboard, plastic sheeting, or anything else that will keep out the rain. The main disadvantage is that observing has to be carried out in the open, so that there is no protection from wind or stray light.

Patrick Moore's 8½-inch equatorial reflector has a proper observatory, with a revolving top section four feet from the base; the sides are partly glassed, for the sake of appearance (the observatory stands on the front lawn). The top revolves on eight ball-races running on an aluminium rail. Finally there is his 15-inch reflector, set up inside a 15-foot diam-



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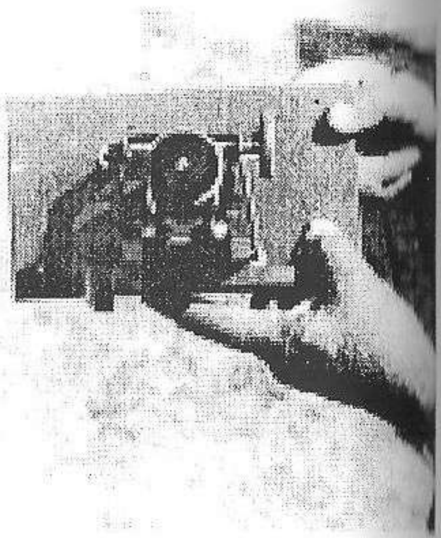

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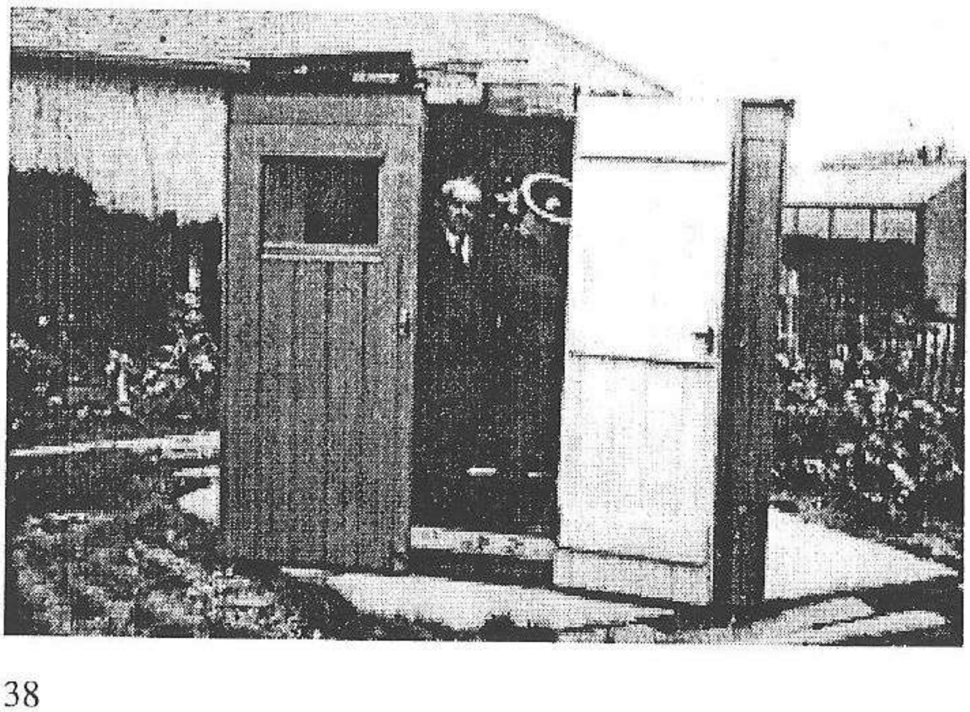


Observatory

eter dome made of metal by the local blacksmith. This also has a revolving top section, and a panel in the roof can be opened for viewing, as well as a window in the side. Both these observatories have roofs which are almost flat, though with sufficient slope to decant the rainfall. They are not hemispherical - and indeed, what is to be gained by having a round observatory with a gracefully domed roof? I have often wondered.

In many, many gardens you will find garden sheds 6 to 8 feet long, looking exactly like my own square observatory, so that nobody will stare at my building in surprise, whereas a dome arouses curiosity; moreover, a square building is the easiest shape to construct. A round one is more difficult, and a hemispherical dome more difficult still. And in a hemispherical dome, an opening which opens and closes easily without sticking, and remains watertight and weatherproof, is something of a miracle. This is, of course, a purely personal opinion; some such domes work perfectly, but I have known many that do not. So when contemplating the making of an observatory, I suggest that you keep everything as simple as possible.

One home-made observatory that I visited was what is often called a "total rotater"; the entire building moved round, not merely the top section. This particular example was octagonal, and was made from some old doors from houses which were being pulled down; it turned round on ordinary furniture casters on a wooden floor. It had to be pushed hard occasionally, but it worked; the observer was sheltered from the wind, the telescope had a watertight home, and much good viewing was obtained. And at.a suggestion from me, another friend laid a flat concrete base, and erected a circular wall one brick high, plastering it around to give a smooth surface so that wheels mounted on a vertical axle kept the building central. Turning was effected on several small pram wheels, mounted in pairs and collected from the local rubbish tip.

Now let me come to my own observatory, which is a total rotater with four flat upright sides and a flat roof. The whole building revolves on a 7-foot diameter track on the base, so that I can have a door 6 feet high, and I do not have to duck when entering. A hinged flap in the roof above the door opens, so that the telescope can swing from the horizontal to the-zenith with no obstruction. A 7-foot square building gives 49 square feet of floor space, as against 38½ feet for a circular one. And I have equal head-room everywhere, not just in the centre - which is occupied by the telescope.

I am all in favour of having an observatory which can be entered easily. Recently I carried out a "test run", when I walked about 50 feet from my back door to the observatory, rotated it 90 degrees or so, went in, uncapped the mirrors and began looking at Jupiter. The time taken was 2 minutes 5 seconds.

One objection is often raised: it is difficult to obtain a steel track upon which the building can turn. I agree, but I may add that I am lucky enough to have a friendly blacksmith almost on my doorstep. The track is perfectly circular, so that I can move the building around by giving a very gentle push with one hand, it moves on ball-races bought from a scrap merchant. But if you think about it, there is no need for the building to spin round like a top. My main interest is in the planets, so that my telescope is usually pointing roughly southwards say from south-east to south-west, all covered by a 90 degree traverse, a Moon enthusiast would move his dome by a mere 15 degrees per hour. (I must agree, however, that the problems of the variable star observer are

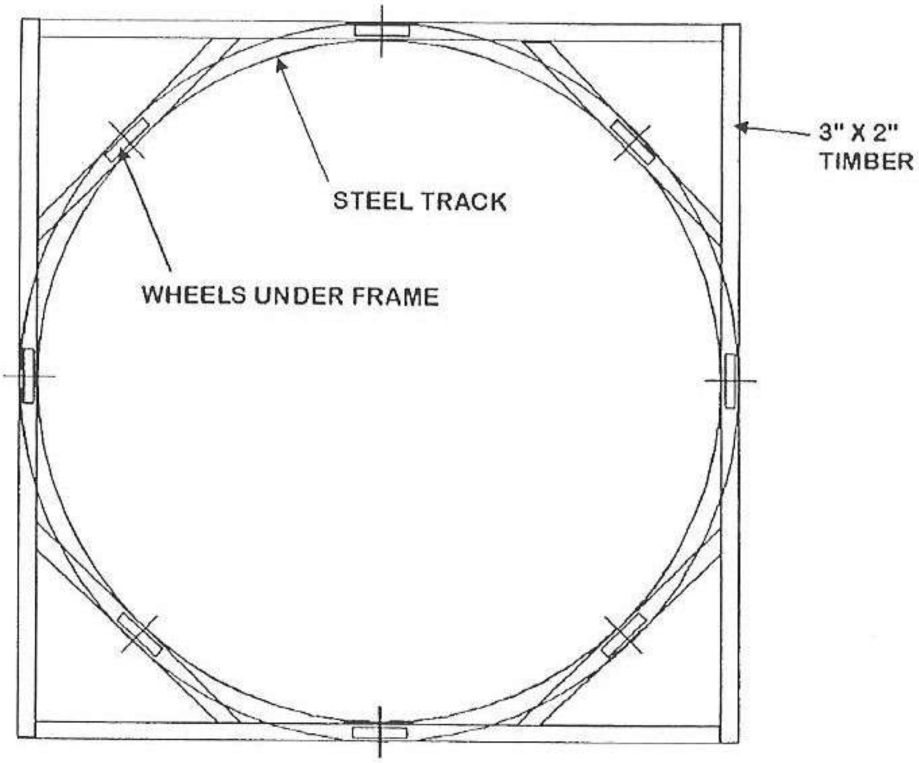


Figure 15.
PLAN OF OBSERVATORY FRAME

different, because he will want to observe variables in all sorts of different- positions in the sky.) Another suggestion for making a "total rotater" is to make a framework which will turn on wheels of some kind. It should be as rigid as possible, and, as always, fixed by screws and not nails, so that alterations can be made whenever necessary.

Assuming that you can manage this, but have not too Much time to spare, and constructing the main body seems likely to be a long process, one of those potting sheds sold at the local garden centre could well be as cheap or cheaper than buying the material and making the observatory up for yourself. The doors of such sheds can often be moved, and it should be fairly easy to adapt the roof for a flap which can be lifted up.

What, then, about wind? As I have said, my observatory revolves easily, and I have often been asked if it has to be anchored down. This has never yet been necessary - and I can assure you that we get plenty of wind on Selsey Bill! The observatory has been in my garden for over five years now, and it has not yet left its moorings, though it has expe-

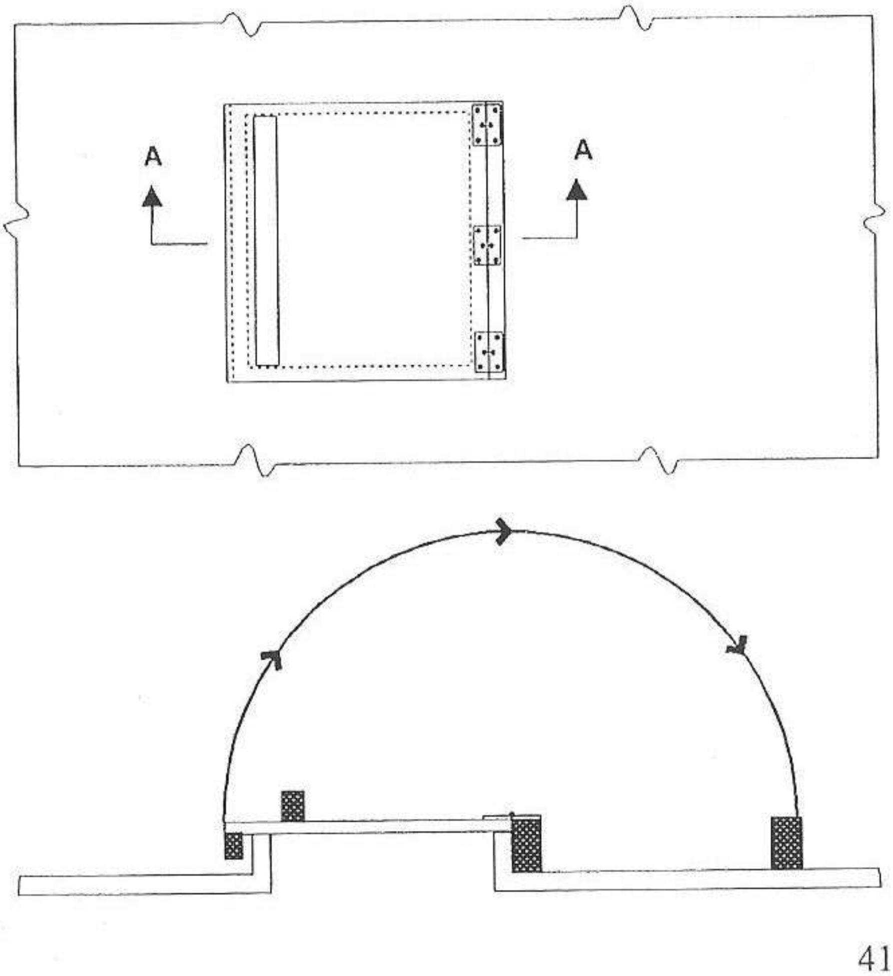


Figure 16.
ROOF PLAN
FOR OBSERVATORY

rienced several force 10 gales blowing around it. The observatory has a concrete base, but even this is not essential.

When I set out to build my observatory, I kept in mind the various others I had seen (for fuller descriptions, see the book *Astronomical Telescopes and Observatories for Amateurs* published by David & Charles), and tried to use all the good points to the best advantage, with ease of operation and construction being first and foremost - together, of course, with low cost. The materials came from an old garden shed, for which I had no further use. Moreover the shed was unsightly, whereas the observatory is not; despite my fondness for using scrap, I do like everything to look neat, particularly when placed in a prominent position in the garden.

Admittedly, the observatory is very utilitarian. Very few people know that there is a telescope inside - unless they have seen it. The 7-foot diameter angle-iron ring was made for £8; eight 2-inch and eight 1-inch ball-races were obtained from a local man who collects useful objects from a nearby rubbish tip - these cost £1. Prices were lower when I made the observatory some years ago, but even now the cost should not be at all high.

A firm, rigid frame was made from 2 x 2-inch timber, 7 feet square outside, with diagonals at the corners to form an octagon; these were well screwed and bolted. Later, planking was screwed to the tops of the corners and sides to ensure greater firmness. Care in this process prevents agreat deal of trouble later on; I am fortunate in having my workshop to make the necessary wheel-housings, but one can manage without. A friend who lives near me made a similar observatory to mine, but using eight pairs of small pram wheels.

Should you put down a concrete base, it is a good idea to lay a length of conduit first, so that any cables can come from a hole in the centre and are not tripped over in the dark. And do not make the door too narrow; stands and apparatus are often wider than you think. Give the roof a reasonable slope, to make sure that rainwater does not collect upon it.

This, then, is my observatory. I can only say that after having used it for years, I am still very satisfied with it.

Using the Telescope

Let it be repeated that there are many books written to help the astronomical observer. To avoid repetition as far as possible, I propose to confine this final chapter to the use of one telescope in particular - the 6-inch reflector which can be made from the instructions given earlier. But, of course, all telescopes are alike in principle, and there is nothing out of the ordinary about this one, apart possibly from the way in which it was made.

Neither do I propose to say much about collimation, i.e. the exact squaring-on of all the optical components. As an oversimplification: remove the eyepiece, uncap the mirrors and look through the eyepiece tubė. The flat should be seen against the centre of the main mirror. If it is not central, then adjust the flat and/or the main mirror itself. Imperfect squaring-on will cause distortion of the images, so that it should always be avoided!

As we have seen, the telescope is an altazimuth, with manual slow motions. This means that it cannot be fitted with a driving motor, and the slow motions, both in right ascension and in declination, have to be used continuously. Ideally, the observer needs three hands - one for each slow-motion rod and one to make general adjustments and notes. Unfortunately not many people have three hands (at least so far as denizens of the Earth are concerned), and itis quite true that the altazimuth stand has its limitations.

There is a temptation to try photography through the telescope. At the risk of sounding pessimistic, it must be said that any such attempts with a 6-inch, undriven altazimuth reflector will almost certainly end in disappointment. By setting the focus of an ordinary camera to infinity, pointing the telescope at the Moon, holding the camera to the eyepiece and giving an exposure of a second or two, somewthing may be recorded; with luck even a crtare or two, but it is more likely the result will be either a blank or a featureless blur, and on the whole it must be dismissed as a waste of film. With any other night-time object, failure is absolutely inevitablle. Photography involves special attachments and, above all, an efficient drive.

On the other hand, it is possible to photograph sunspots by the projection method. On no account put your eye anywhere near the eyepiece when the telescope is turned sunward. To focus the Sun's heat on to your eye will mean permanent blindness - and this is not mere alarmism, because it has happened on quite a number of occasions. Neither is it safe to put a dark filter over the eyepiece or the endof the open tube, to cut down the light, and then look direct. No filter can give really complete protection. In any case, a filter is apt to crack, shatter or dissolve under the Sun's heat at any moment, with tragic results. There is, in fact, one golden rule about looking directly at the Sun through any telescope, or even a pair of binoculars: DON'T.

However, the telescope may be used to project the Sun's image on to a screen. For this, first point the telescope in the direction of the Sun by squinting along the top of the tube (not looking through the fnder!); then hold a card behind the finder, and centre the small, brilliant solar disk in the middle of the field shown on the screen. Now move the screen to a position behind the eyepiece of the main telescope, and focus up. The Sun will be projected, and any spots which happen to be present will be seen. Obviously, the screen can then be photographed with an ordinary camera, the main difficulty being to get the screen in the camera field "square-on". Inevitably the telescope itself will get in the way, and the final picture is bound to be distorted, but it will be better than nothing at all.

Frankly, a reflector is by no means ideal for Sun projection, and a small refractor is better. Takegreat care not to leave the telescope turned sunward for too long, as the result will be overheating of the optics. On a brilliant sunny day it is also wise to cut down the aperture by placing a screen over the open end of the tube, leaving, say, a 4-inch aperture.

It is often said that during the daytime it is possible to see Venus. This is true, and when the telescope is equipped with an equatorial mount and setting circles there is no problem in finding the planet except when it is near conjunction. Books have been written in which it is suggested that with an altazimuth the sky may be "swept" until Venus is found, but this is a most risky and foolhardy procedure, because there is always a strong chance that the Sun will come into the field of view. With an altazimuth, never look for Venus (of Mercury) until the Sun has actually set, or in the early morning before the Sun has risen.

Obviously the Moon is the most spectacular of all objects for our 6-inch, and here a relatively high magnification can be used. The craters, mountains, valleys and all the other features are truly superb, and the enthusiast who equips himself with an outline lunar map will soon find his way around. Craters are best seen when near the terminator, or boundary between the sunlit and night hemispheres, because they are then partly filled with shadow, and they stand out well. Full moon is the worst possible time to start observing, because there are virtually no shadows; the whole lunar scene is dominated by the bright ray systems from craters such as Tycho, and gives an impression of total confusion.

Sometimes the Moon passes in front of a star, and hides or occults it. These occultations are valuable, because exact timings of them are needed to give the Moon's own position at that moment. A 6-inch is ideal for the purpose, though a stopwatch is needed as well. Even more important are "graze occultations", when the star skirts the Moon's upper or lower limb; and since the 6-inch is portable, it can be put into a car and taken to the "graze line". The magnification needed depends upon the faintness of the star. As always, use the highest power which will give a sharp image, and will show the star so clearly that its moment of disappearance - or "winking", as it passes behind a mountain on the Moon's limb - can be noted and timed.

The telescope is also well suited to observation of the planets. Venus shows its characteristic phases, if little else; Mars is a tricky object, because even when at its best a high power is needed to show the surface features, and here the altazimuth, with its inability to be automatically guided, is at a disadvantage. But Jupiter and Saturn more than compensate. Jupiter is a quick spinner, and the Surface markings drift perceptibly across the disk even over a period of a few minutes, so that they can be timed as they cross the planet's central meridian - and this leads to determinations of the longitudes of the features concerned. The only mathematics needed involve simple addition and subtraction, using the tables given in the *Handbook* of the British Astronomical Association. Also, the eclipses, transits, and occultations of the four bright Jovian satellites are spectacular. Saturn shows its wonderful ring system, and the telescope is powerful enough to show five of the satellites (Titan, Iapetus, Rhea, Dione, and Tethys). Of the other planets, Uranus will show a perceptible disk; Mercury, when it can be glimpsed, will reveal its phase; and Neptune will be identifiable, though it will look very like a star. Of the principal members of the Sun's family, only Pluto is beyond the range of a 6-inch.

Comets, when they appear, can be well seen, using a wide-field eyepiece. Unfortunately all the short-period comets are dim, and not easy to find with an altazimuth; but brilliant visitors appear now and then (West's Comet of 1975 was the last to date), and we can always look forward to the return of Halley's Comet in 1986!

For stellar observation, a low-power, wide-field eyepiece is the best for most purposes, and there are numerous clusters and nebulae available. Look, for instance, at the Orion Nebula, in the Sword below the Hunter's Belt; the shining gas is magnificent, and a slightly higher power will bring out the four main stars of the celebrated "Trapezium", Theta Orionis, which is responsible for lighting up the nebula. Of the open clusters, the Pleiades and the Hyades in Taurus, and Praesepe in Cancer, are particularly notable use the lowest power you have, so as to get all the cluster in the field at once. The double cluster in Perseus is another superb sight, but my own favourite is the fan-shaped "Wild Duck" cluster, Messier 11, in the little constellation of Scutum (the Shield), below Aquila. In Hercules, the great globular cluster Messier 13 will show individual stars, at least in its outer sections.

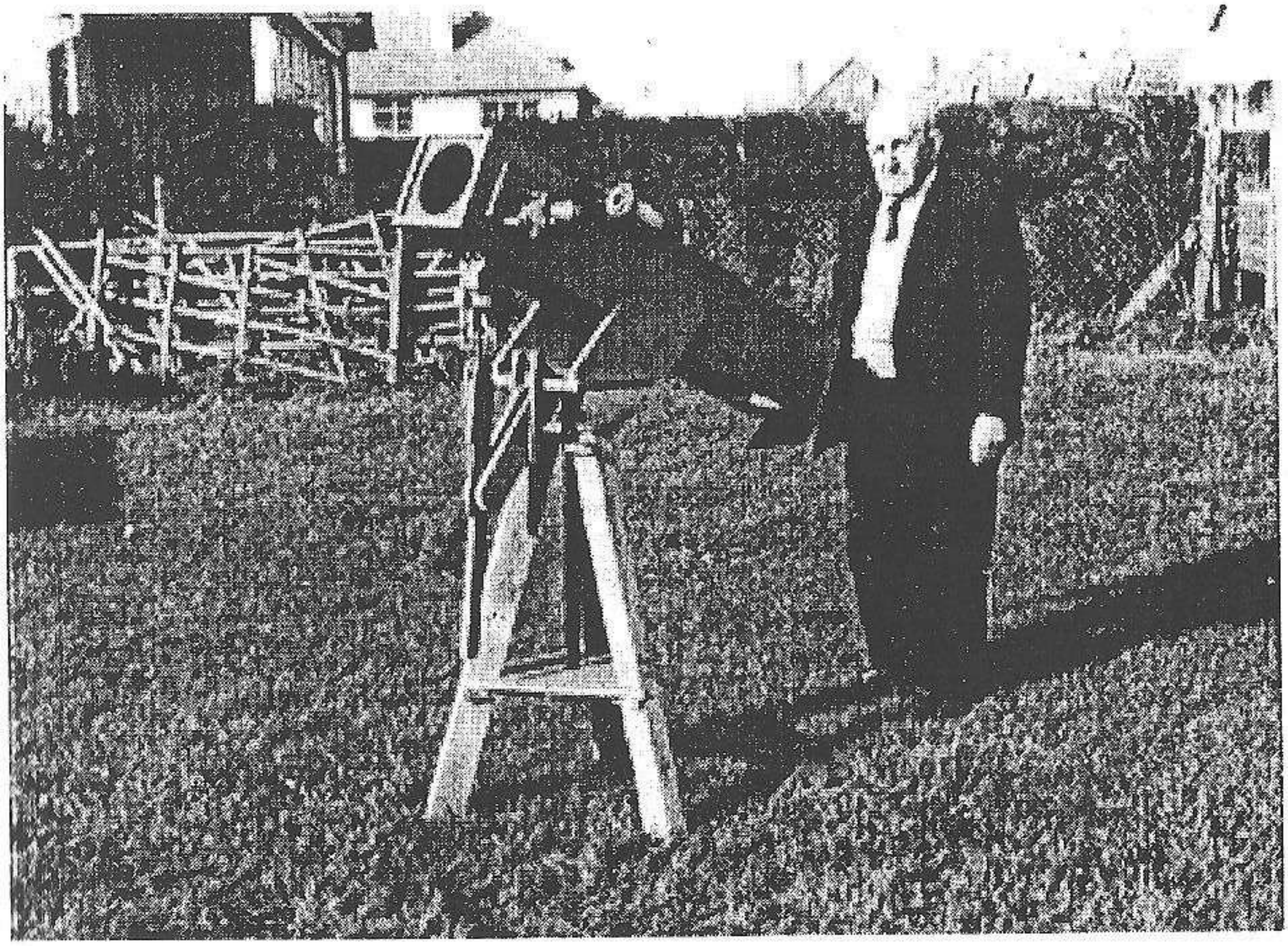
Double stars abound, some with contrasting colours; look at Beta Cygni or Albireo, in the Swan, where the yellow primary is attended by a blue companion. Then, of course, there are the variable stars - and here the 6-inch altazimuth really comes into its own.

A variable star is exactly what its name implies. Instead of shining steadily, as most stars do, it waxes and wanes over a relatively short period - which may be a few hours, a few days, or several months. The method of gauging the brilliance of a variable is to compare it with nearby stars (that is to say, in or very near the same telescopic field), which do not change. With a little practice these estimates can be made surprisingly accurate; and since there are many variable stars which are unpredictable to a greater or a lesser degree, professional astronomers are always glad to have observations of them.

There are large numbers of variables within the range of a 6-inch telescope - more, indeed, than can be coped with by any single observer. Though variable star work may not be so spectacular as lunar study, comet-hunting or planetary drawing, it is one of the most valuable of all branches of amateur astronomy today, and a 6-inch altazimuth gives the enthusiast practically unlimited scope. Generally speaking, a reasonably low power is required, though each variable will be found to have characteristics of its own.

These are only some of the wonders which the home-made 6-inch reflector will show. The telescope will provide endless enjoyment, and this enjoyment will be all the greater if the instrument is of one's own construction. If this book spurs on even one beginner to make the attempt, I feel that it will have been well worth writing.

The Author's completed telescope, Mark 2



Some Don'ts

DON'T begin with an untidy floor. Make it easy to find anything which has fallen.

DON'T clutter up the workbench. Put each tool away directly after you have used it. This may sound fussy, but it saves a great deal of time in looking for the lost.

DON'T use blunt tools. Sharp tools produce better work more quickly. Time spent in sharpening is invested, not wasted.

DON'T use nails. Screws are easily extracted if necessary (especially if inserted with a touch of grease first). Nails are difficult to get out without causing damage.

DON'T use glue unless the fixing is to be permanent. Remember that replacements or modifications may always be necessary.

DON'T cut sideways with a pad-saw; always cut straight down. You then get square edges. When cutting circles, keep moving the wood, even if only slightly; this will give better results.

DON'T be too hasty. Remember to measure twice before cutting once.

DON'T empty the workshop waste-box just before the dustmen come. Do so on the next day. Why? Well - if something has fallen into the box by mistake, you have a week's grace to find it.

MAKE YOUR OWN TELESCOPE

From Everyday Materials

REG SPRY

This book by Mr Spry is unique because it concentrates on the 'hardware' of telescope making, assuming that the optics have already been obtained, whereas most books concentrate on the optics.

The author describes his 6 - inch reflector and how it was made using such items as coffee-jar tops, Meccano and a car half-shaft. The 'tube' is made from two shelves. His description is full and simple with 16 line diagrams to make it easy for beginners to follow. Twelve half-tone pictures both aid and illustrate the author's instructions.

Mr Spry emphasizes that he set out to make a good simple telescope using as few tools as possible, the basic four being a pad saw (or keyhole saw), tenon or hand saw, wheel brace and drills, and a screwdriver. Readers and would-be builders need have no doubt of the functional qualities of the end product, for Patrick Moore says in his foreword to the book: "I have used the telescope many times and it is probably the most convenient 6 - inch reflector I have ever handled".

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